

**Shasta Lake Water Resources Investigation,  
California**

**Mission Statement Milestone Report**

**APPENDIX A**

**SUPPLEMENTAL INFORMATION FOR  
EXISTING CONDITIONS**

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## **APPENDIX A**

### **SUPPLEMENTAL INFORMATION FOR EXISTING CONDITIONS**

One of the most important elements of any water resource evaluation is properly defining the scope of problems needing to be solved and opportunities to be addressed. Important in this process is defining existing resource conditions. Several of the major resource issues in the study area are complex and interrelated (water quality, aquatic resources, riparian habitat). This attachment provides additional information on the existing conditions for the study area.

#### **SACRAMENTO RIVER BASIN**

The Sacramento River Basin encompasses approximately 26,300 square miles, including all or some portions of 20 counties in northern California. As of January 1, 2002, these counties had a combined population of 3.3 million persons. The western, northern, and eastern portions of the Basin are heavily forested, mountainous areas consisting of the Coast Range, Cascade Mountains, and the Sierra Nevada. Most land within these areas is federally owned and managed by the following National Forests: Mendocino, Shasta-Trinity, Lassen, Plumas, and Tahoe. In contrast, the central and southern portions consist mainly of flat to rolling farmland. The Basin's primary employment and population centers include the Redding, Yuba City-Marysville, Sacramento, and Fairfield metropolitan areas.

The Sacramento River originates at Mount Shasta, about 40 miles north of Shasta Lake. This portion of the river, which receives runoff from small tributaries in the Mount Shasta, Trinity, and Klamath Mountains, is primarily forested with mixed conifer species at higher elevations and oak woodlands, scattered pine, and brush at lower elevations.

Inflows into Shasta Lake also are derived from three principal tributaries—the Mc Cloud River, Pit River, and Squaw Creek. From Shasta Lake, the Sacramento River flows into Keswick Reservoir and then south for 302 miles, terminating at the Sacramento-San Joaquin Delta south of Sacramento near Collinsville. Major tributaries of the Sacramento below Shasta Lake include the Feather River, American River, and Stony Creek.

The climate of the Basin is characterized by very hot, dry summers and cool, wet winters. Yearly precipitation ranges from 50 to 70 inches, almost entirely as rain.

#### **Shasta Lake**

Shasta Lake, California's largest reservoir, has (at its maximum elevation) 29,500 surface acres, a maximum depth of 517 feet, and 370 miles of shoreline, which varies from steep and rocky banks to coves of wooded flats.

#### ***Primary Lake Tributaries***

As noted above, Shasta Lake has three principal tributaries. These originate in the northeastern portion of the Basin and flow westward into Shasta Lake. They are described below.

- **McCloud River** – The McCloud River basin drains an area of roughly 800 square miles. Its headwaters are at Colby Meadows near Bartle. The river flows southwesterly for approximately

50 miles to its terminus at Shasta Lake. Completion of Shasta Dam in 1949 inundated fifteen miles of the lower McCloud and prevented returning salmon and steelhead from reaching spawning areas in that river.

- **Pit River** – The north fork of the Pit River originates at the outlet of Goose Lake, and the south fork originates in the south Warner Mountains at Moon Lake in Lassen County. The river, which has 21 named tributaries totaling about 1,050 miles in length, provides 20 percent of inflow to Shasta Lake.
- **Squaw Creek** – The Squaw Creek watershed is located east of Shasta Lake, drains 103 square miles, and has over 108 miles of streams that are watered year round.

## **PHYSICAL ENVIRONMENT**

### **Topography**

Shasta Dam and Reservoir are located on the northern edge of California's Central Valley, which is almost completely enclosed by mountains and has only one outlet, through the San Francisco Bay to the Pacific Ocean. The valley is nearly 500 miles long and averages 120 miles in width. The Central Valley is drained by the Sacramento River in the northern portion and the San Joaquin River and Tulare Lake tributary streams in the southern portion.

The major tributary drainages above Shasta Dam, Sacramento, McCloud, and Pit rivers, and several smaller drainages, originate in the east and flow generally westward into Shasta Lake. Downstream from the Dam, the Sacramento River travels south to the Delta, picking up additional flows from numerous tributaries including Cottonwood Creek, Stony Creek, the Feather and American rivers, and others. The Sacramento River Basin covers approximately 27,000 square miles and is about 240 miles long and up to 150 miles wide.

Ground surface elevations in the northern portion of the Sacramento Valley range from above 14,000 feet at Mount Shasta in the headwaters of the Sacramento River to approximately 1070 feet at Shasta Lake. About 65 percent of the mountainous area within this range lies below 4,000 feet in elevation and 97 percent below 7,000 feet in elevation. Total annual precipitation averages between 60 and 70 inches and is as high as 95 inches in the northern Sierra Nevada and the Cascade Range. As much as 90 inches of precipitation falls at Lassen Peak, which exceeds 10,000 feet in the Cascade Range. Other mountain areas bordering the valley reach elevations higher than 5,000 feet and receive an average of 42 inches of precipitation per year, with snow prevalent at higher elevations. In the southern portion of the Sacramento River Basin, the Sacramento Valley floor is relatively flat. Elevations range from 20 inches in the northern end of the valley to 15 inches in the Delta.

The landscape of the area north of Shasta Lake was modified during the late 1800's and early 1900's when copper smelting brought about the removal of large tracts of forested areas, resulting in extensive soil erosion. As a consequence of this erosion, the region's gently sloping terraces were transformed into steep-sided gullies up to 20 feet deep. The gullies continued to erode for many years after smelting ended in 1910. Despite a massive effort to plug and dam the gullies from 1910 to 1960, they are only beginning to stabilize today (U.S. Forest Service (FS), 2001).

Within the 12-mile-long section between Shasta Dam and Redding, the Sacramento River falls 560 feet. Keswick Dam, located between Shasta Dam and Redding, confines river flows in an incised canyon, which extends upstream almost to Shasta Dam. Below Redding, the river emerges onto a relatively level, broad, alluvial plain, where it has traditionally meandered through the area's deep alluvial soils, eroding and depositing sediments during periodic flood events.

## **Geology**

A "geomorphic province" is an area with similar geologic origin and erosional/ depositional history. The primary study area is located within the juncture of two such geomorphic provinces: the northern Great Valley province, which includes the Sacramento River corridor below Redding; and the southern Klamath Mountains province, which contains Shasta Lake and the Sacramento River corridor from Shasta Dam to Redding. Two types of recent deposits are distinguished: Alluvium, and landslide deposits. Little residual soil remains on the higher slopes, but in places these slopes are covered with rock debris or with a thin layer of soil and rock debris. Alluvium and surface mantle are limited to valleys and low foothills. Areas in the higher foothills and mountains are covered with a mixture of coarse and fine rock debris that contains enough soil in the interstices of the rocks at many places to support a dense growth of chaparral. Above Red Bluff, much of the river corridor consists of bedrock geomorphology (State Resources Agency, 1989). However, much of the adjacent floodplain is comprised of both Pliocene and Pleistocene fill mostly deposited from the Sierra Nevada.

The Klamath Mountains province is considered to be a northern extension of the Sierra Nevada. It consists of rugged topography with prominent peaks and ridges. The drainage of this province is primarily through the Klamath and the upper Sacramento rivers. Rocks include pre-Cretaceous metamorphic, abundant serpentine, and granitics.

Some lower slopes have accumulated rock debris and soil as much as 100 feet thick. The unstratified deposit is composed of rock fragments as much as one-foot in diameter in a matrix of red soil. This unusually thick mantle was formed by colluviation and rain wash from the higher slopes, many of which are now bare. The eroded material aggraded lower slopes, and the increased runoff on the denuded upper slopes accelerated the process.

Most of the streams are cutting narrow "V"-shaped canyons where bodies of harder rocks have impeded down cutting. A few streams have reaches with a low gradient and some gravel fill. The large streams at some places cut more rapidly than the tributaries, and the latter have discordant junctions (FS, 2001).

Shasta Lake lies within the Eastern Klamath Belt consisting of old ocean floor, volcanic rocks, and sedimentary formations (Alt and Hyndman, 2000). It is situated within the Klamath Mountain Geomorphic Province, which ranges in age from Devonian to Recent.

The Great Valley province (also referred to as the Central Valley) is a large, asymmetrical, northwestwardly trending, structural trough formed between the uplands of the California Coast Ranges to the west and the Sierra Nevada to the east. This trough has been filled with a tremendously thick sequence of sediments ranging in age from Jurassic to Recent. The Great

Valley is over 400 miles long and approximately 50 to 60 miles wide in the primary study area. The northern portion of the Great Valley is bounded on the east by the Cascade Ranges, and on the north and west by the Klamath Mountains.

Sediments that form the thick valley sections in the primary study area were largely derived from erosion of these surrounding mountain ranges. These sediments consist predominantly of loose, recently deposited silts underlain (at relatively shallow depths) by Holocene-age alluvium of the Riverbank Formation. In general, the Riverbank Formation is composed of weathered reddish gravel, sand, and silt that form clearly recognizable alluvial terraces and fans.

The region within which this project lies is considered to have a relatively low seismic potential. The closest known active fault (or fault zone) mapped by the California Division of Mines and Geology is the Hat Creek - McArthur - Mayfield fault zone, located approximately 55 miles to the northeast of the site (*Fault Activity Map of California and Adjacent Areas*, 1994). Other significant active faults (or fault zones) located within the site region include the Cedar Mountain - Mahogany Mountain fault zone, located to the northeast, and the Trinidad fault, located to the west.

## **Soils**

Soil conditions in the Shasta Lake area are broadly categorized into three types: thermic alluvial terraces; mesic and thermic metamorphic side slopes and ridges; and thermic metamorphic rock outcrops (FS, 2001).

Below Shasta Dam much of the primary study area is typified by deep, unconsolidated soils deposited as an ancient floodplain of the Sacramento River and its tributaries.

Soil parent materials in the watershed can be characterized as metamorphic rocks, deep alluvium, or sedimentary rocks (limestone). Soils overlying metamorphic rocks are generally shallow to moderately deep and very gravelly; erosion potential is moderate to low. Soils overlying alluvium are deep, fine-textured and mostly unconsolidated; erosion potential is high to very high. Below these near-surface soils, medium-dense to very dense silty sand/gravel (with cobbles and possible boulders) was encountered to the maximum depth explored (approximately 16.5 feet below existing site grade).

## **Geomorphology**

The geomorphology of the Sacramento River is a product of several factors: the geology of the Sacramento Valley, hydrology and climate, vegetation, and human activity. Large flood events drive lateral channel migration and remove large flow impediments. Riparian vegetation stabilizes stream banks and reduces water velocities, inducing deposition of eroded sediment. In the past, a balance existed between erosion and deposition along the Sacramento River. However, the construction of dams, levees, and water projects has altered stream flow and river hydraulics of the Sacramento River. In some areas, human-induced changes have stabilized and contained the river, while in other reaches the loss of riparian vegetation has reduced sediment deposition and led to increased erosion.



The upper Sacramento River between Shasta Lake and Red Bluff is bounded and underlain by resistant volcanic and sedimentary deposits that confine the river, resulting in a relatively stable river course. This reach of river is characterized by steep vertical banks and the river is primarily confined to its channel with limited overbank floodplain areas. There is limited meander of the river above Red Bluff. Downstream from Red Bluff, the Sacramento River is active and sinuous, meandering across alluvial deposits within a wide meander belt. Geologic outcroppings and man-made structures, such as bridges and levees, act as local hydraulic controls along the river. Bank protection, consisting primarily of rock riprap, has been placed along various sections of the Sacramento River to prevent erosion and river meandering.

## Hydrology

The Sacramento River Region contains the entire drainage area of the Sacramento River and its tributaries and extends almost 300 miles from Collinsville in the Delta north to the Oregon border. Hot, dry summers and mild winters characterize the valley floor. Precipitation on the valley floor occurs mostly as rain, and yearly totals range from 20 inches in the northern end of the valley to about 15 inches at the Delta. Average annual precipitation throughout the basin is 36 inches, and average annual runoff is approximately 22 million acre-feet (MAF). The most intensive runoff occurs in the upper watershed of the Sacramento River above Lake Shasta and on the rivers originating on the west slope of the Sierra Nevada. These watersheds produce an annual average of 1,000 to more than 2,000 acre-feet of runoff per square mile.

Flood frequency hydrographs were developed in 1985 for the winter season and are summarized in **Table 1**. An updated frequency flood study has been recommended for future feasibility-level studies.

**TABLE 1**  
**FREQUENCY FLOODS FOR SHASTA DAM**

Frequency	Volume (150day)(acre-feet)	Peak inflow (cfs)
25-year	1,773,400	187,000
50-year	2,016,900	219,000
100-year	2,235,600	251,000

Mean monthly streamflow data for Shasta Dam from 1922 to 1996 was obtained from Water Supply reports and was averaged to represent normal inflow conditions. These values range from less than 4,000 cfs (from July through October) to nearly 14,000 cfs (in February and March), as indicated in **Table 2**.

Determination of a probable maximum flood (PMF) is an estimation of the largest flood that is likely to occur within a basin. This flood is used as a design tool to establish spillway capacities and the size of other physical features incorporated into the dam. The current PMF for Shasta Dam has a peak inflow of 623,000 cfs and a 15-day volume of 4,266,000 acre-feet. This PMF was developed in 1984 using appropriate data available at that time. A review of these data indicates that the PMF peak inflow is about 91 percent of the current value. The new 15-day volume for the revised PMF is estimated to be about 80 percent of the existing PMF volume. Formal determination of the new PMF will need to be performed for future feasibility-level

studies. A smaller design PMF would enable a more efficient design of the spillway, thereby allowing more storage for any given height increase.

**TABLE 2**  
**MEAN MONTHLY STREAMFLOW DATA, SHASTA RESERVOIR**

Month	Streamflow (cfs)	Month	Stream flow (cfs)
January	11,201	July	3,815
February	13,981	August	3,430
March	13,609	September	3,482
April	11,603	October	3,963
May	8,189	November	5,637
June	5,339	December	8,525

## **Sedimentation and Erosion**

### ***Introduction***

This section discusses sedimentation and erosion in the primary study area. The primary study area includes the Sacramento River between Keswick Dam and the Red Bluff Diversion Dam (RBDD), Shasta Lake and Keswick Reservoir, and the lower reaches of the major tributaries to the reservoir (the little Sacramento, McCloud, and Pit rivers, and Squaw Creek), which will be inundated if Shasta Lake is enlarged.

Excessive and improperly managed slope grading, vegetation removal, quarrying, logging, agricultural practices and forest fires all lead to increased erosion and sedimentation of streams and rivers, especially during periods of high rainfall or snowmelt. In slow moving water bodies, including reservoirs, suspended sediments settle out. This siltation potentially reduces the capacity of the floodplain to percolate and recharge groundwater basins, and may adversely affect both aquatic resources and flood control systems. Sedimentation and erosion play a major role in maintaining the quality of in-stream and riparian habitat for fish and wildlife species, particularly in alluvial reaches of rivers.

### ***Areas Upstream of Keswick Dam***

Sedimentation and erosion are natural features of the primary study area upstream of Keswick Dam, because most of the watershed in this area is steep and mountainous. Landslides are relatively common in this area because many of the canyon slopes are oversteepened. Slides range from small mudflows and slumps to large debris slides, debris flows, or landslides that are thousands of feet across. Slides and sheet wash supply debris and bedload sediments to the streams during the rainy season. Early in the 20<sup>th</sup> century, erosion in some areas upstream of where Shasta Dam is currently located was greatly accelerated by removal of timber for mining purposes and destruction of vegetation by fumes from smelters. Following the creation of Shasta Lake, intensive erosion control programs, including revegetation, were employed to minimize hillside erosion in the affected areas. Currently, the watershed of Shasta Lake is generally well forested and erosion is not excessive. Many of the reservoir's tributaries are well balanced systems, where flows, bedload and the delivery of large woody debris are in dynamic

equilibrium, resulting in the formation and maintenance of essential fisheries habitat features (deep pools, riffles, and runs).

The principal current issues of concern regarding sediment and erosion in the Shasta Lake - Keswick Reservoir watershed are runoff associated with timber harvest activities and roads, including logging roads (FS web site: [www.r5.fs.fed.us/shastatrinity/manage/reading/wa](http://www.r5.fs.fed.us/shastatrinity/manage/reading/wa)). Also of concern are erosion and sedimentation from slopes denuded by fires, including the High Complex Fire in 1999.

### ***Sacramento River between Keswick Dam and the RBDD***

When unimpaired, any river works as a conveyor of sediment, transporting materials eroded from the upper reaches and depositing them in the lower ones. The balance between the amount of sediment available and the amount that the river is capable of transporting determines the stability of the channel of the river. When there is more sediment available than the river is able to carry, sediment is deposited and the riverbed will aggrade (bed elevation increases). If there is less sediment available than the river is able to carry, the riverbed tends to degrade.

The main effect of Shasta and Keswick Dams on sediment transport has been to block the sediments that would normally have been transported from the upper Sacramento River Basin. The result has been a net loss of sediment in the Sacramento River below Keswick Dam. The high winter and spring flows discharged from Keswick Dam contain a low sediment load and therefore transport sediments from the riverbed below the dam further downstream.

One consequence of this process has been a steady loss of spawning gravels from the river in the Keswick to Clear Creek reach. Below Clear Creek, tributary streams increase in importance as a source of spawning gravels to the Sacramento River. The problem of gravel availability in the Sacramento River is exacerbated downstream of Keswick Dam by dams constructed on Sacramento River tributaries, bank protection measures in the mainstem of the Sacramento River, and gravel mining enterprises. In the recent past, the U.S. Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), and California Department of Fish and Game (DFG) have cooperated in actions to artificially replenish salmon spawning gravel in the reach (Reclamation, 1997).

In alluvial river sections, bank erosion and sediment deposition cause migrations of the river channel that are extremely important in maintaining instream and riparian habitats, but may also cause loss of agricultural lands and damage to roads and other structures. In the Sacramento River, these processes are most important in the major alluvial section of the river, which begins downstream of the RBDD. The river channel in the Keswick to RBDD reach is more constrained by erosion-resistant volcanic and sedimentary formations and, therefore, is more stable (Reclamation, 1997).

### **Flood Control**

Various areas in Shasta County are subject to flooding by rivers and creeks. Floods on the Sacramento River are caused primarily by winter rainstorms augmented by melting of accumulated snow on the drainage area. Flood flows originating above the dam are generally confined to canyons and stream channels, and travel rapidly to the lake without causing

significant damage. Below Shasta Dam local tributary inflow to Sacramento River flows in streams confined to narrow canyons above the foothill line, below which the streambed gradient decreases sharply and flood flows tend to spread over wide areas if not confined by levees. Floods caused by rain are characterized by high peak values and short durations, while snowmelt floods may produce moderately high flows over a sustained period of several weeks.

Areas along the Sacramento River downstream from Shasta Dam that are subject to flooding consist of the towns of Redding, Anderson, Red Bluff, and Tehama. Also subject to flooding are agricultural lands and industrial developments. Large floods may inundate over 200,000 acres. About half of the flooding occurs within the confines of dedicated floodways and natural overflow basins.

Between 1900 and 1991, there have been no less than sixteen severe floods in the Sacramento River Basin. The Federal Emergency Management Agency has developed maps and created reports related to the floodplain and floodways for various creeks in Shasta County, which have experienced or are expected to experience significant development.

Shasta Dam serves as a flood control device for the Shasta County area. The current regulation of Shasta Dam for flood control requires that releases be restricted to quantities that will not cause downstream flows or stages to exceed, (1) a flow of 79,000 cfs at the tailwater of Keswick Dam, and (2) a stage of 39.2 feet at the Sacramento River at Bend Bridge gaging station, near Red Bluff (corresponds roughly to a flow of 100,000 cfs). Storage space of up to 1.3 MAF below elevation 1,067 is also kept available for flood control purposes in the reservoir in accordance with the Flood Control Diagram, as directed by the U.S. Army Corps of Engineers.

## **Water Quality**

### ***Introduction***

This section discusses water quality in the primary study area. The primary study area includes the Sacramento River between Keswick Dam and RBDD, Shasta Lake and Keswick Reservoir, and the lower reaches of the major tributaries to the reservoir (the little Sacramento, McCloud, and Pit rivers, and Squaw Creek), which will be inundated if Shasta Lake is enlarged.

The State Water Resources Control Board and the regional water quality control boards largely determine objectives for water quality in California's surface waters. The primary study area lies entirely within the region under jurisdiction of the Central Valley Regional Water Quality Control Board (CVRWQCB). Water quality objectives for this region are described in the Basin Plan for the Central Valley (CVRWQCB, 1998).

The water quality objectives for a particular reservoir or river reach are influenced by its beneficial uses, which are determined by the Regional Board. The water quality must adequately protect the beneficial uses. The beneficial uses for Shasta Lake and its tributaries, and the reach of the Sacramento River between Shasta Dam and the Colusa Drain (which includes Keswick Reservoir and the river between Keswick Dam and RBDD) are provided in **Table 3**.

Water quality in the primary study area generally supports the beneficial uses of the area's rivers and reservoirs (U.S. Geological Survey (USGS), 2000). However, impaired water quality

conditions have been found for specific waters of the primary study area in the recent past; further, some of these impaired conditions persist. The principal water quality issues for the primary study area include water temperatures in the Sacramento River between Keswick Dam and the RBDD, turbidity in Shasta Lake, and acid mine drainage and associated heavy metal contamination from the Spring Creek drainage and other abandoned mining sites.

Elevated pesticide levels have been found at some sites in the Sacramento River Valley for a number of years, but these sites are downstream of Red Bluff, where agricultural drainage affects water quality (USGS, 2000). Storm water runoff from Redding and other urban areas likely flushes contaminants into the Sacramento River, but the volume of flow in the river generally provides sufficient dilution to prevent excessive concentrations in the river.

The remainder of this section examines general water quality conditions and specific issues for three major geographic divisions of the primary study area: the lower reaches of the major tributaries to Shasta Lake, Shasta Lake, Keswick Reservoir (including the Spring Creek Drainage), and the Sacramento River from Keswick Dam to RBDD.

**TABLE 3**  
**BENEFICIAL USES FOR THE SURFACE WATERS IN THE PRIMARY STUDY AREA**

Beneficial Use	Pit River (Hat Creek to Shasta Lake)	McCloud River	Sacramento River, Box Canyon Dam to Shasta Lake	Shasta Lake	Sacramento River (Shasta Dam to Colusa Drain)
Municipal & domestic supply (drinking water)	E*	E		E	E
Agriculture, irrigation	E		E	E	E
Agriculture, stock watering	E		E		E
Industry, Service Supply					E
Industry, Power	E	E		E	E
Recreation, contact	E	E	E	E	E
Recreation, whitewater	E	P	P		E
Recreation, noncontact	E	E	E	E	E
Freshwater habitat, warm	P			E	P
Freshwater habitat, cold	E	E	E	E	E
Migration, warm					E
Migration, cold					E
Spawning, warm	E			E	E
Spawning, cold	E	E	E	E	E
Wildlife habitat	E	E	E	E	E
Navigation					E

\* E refers to an existing beneficial use, P refers to a potential beneficial use

### ***Tributaries to Shasta Lake***

Water quality is excellent in the lower reaches of the little Sacramento River, the McCloud River, Squaw Creek, and the Pit River. Most of the watershed of these streams is forested, with few point-source discharges. Sediment runoff from the few roads in the area, including logging roads, is a significant concern (FS web site: [ww.r5.fs.fed.us/shastatrinity/manage/reading/wa](http://ww.r5.fs.fed.us/shastatrinity/manage/reading/wa)).

Elevated turbidity is generally restricted to the winter and spring, during periods of intense rainfall and flood flows (North State Resources, Inc., 2003).

Water quality in Town and Horse creeks, minor tributaries to the Squaw Creek arm of Shasta Lake, has been impaired by acid mine drainage and associated heavy metals contamination originating from historic mining activity near these streams. Little Backbone Creek and West Squaw Creek, which drain the western slope of Shasta Lake near the dam, are biologically dead in some reaches because of effluents from historic mining activity. During periods of heavy rain, increased discharges from these streams have caused fish kills in Shasta Lake (FS web site: [www.r5.fs.fed.us/shastatrinity/manage/reading/wa](http://www.r5.fs.fed.us/shastatrinity/manage/reading/wa)). Measures that have been implemented to reduce the effects of acid mine drainage in these creeks have resulted in improved water quality there.

### ***Shasta Lake and Keswick Reservoir***

Water quality in Shasta Lake is considered to be very good (FS web site: [www.r5.fs.fed.us/shastatrinity/manage/reading/wa](http://www.r5.fs.fed.us/shastatrinity/manage/reading/wa)). The only significant water quality problems are occasional discharges of acid mine drainage from the small creeks listed in the previous section and elevated turbidity levels. Some of the heavy metals in the acid mine drainage precipitates out of solution and accumulates in bottom sediments, possibly affecting benthic organisms.

Factors contributing to the turbidity in the reservoir include sediment-laden discharge from tributaries during periods of high rainfall, shoreline erosion from wave action, and water level fluctuations. Fine-textured clays that line much of the reservoir perimeter are the source of most turbidity during periods of low water level. Plankton blooms also contribute to turbidity during the spring (Lieberman and Horn, 1998). High turbidity is primarily a problem for recreational enjoyment of the reservoir, but it may adversely affect feeding and egg survival of fish. If sediments are flushed downstream into the Sacramento River, they may adversely affect spawning habitat of listed anadromous salmonid species.

Shasta Lake's water temperature structure provides both cold-water and warm-water habitat conditions. The reservoir is classified as warm monomictic because it has one period of mixing per year. During a limnological survey conducted during 1995 through 1997, the reservoir mixed during the winter months and was thermally stratified from late April through the end of September (Lieberman and Horn, 1998). Because of the reservoir's great depth, however, the mixed layer extended only about 160 feet below the surface. The maximum depth at full pool is 517 feet. During the period of summer stratification, the warm surface layer, or epilimnion, was about 30 feet deep. Water temperatures in this layer, which peaked at about 80 degrees Fahrenheit during August, provide suitable conditions for warm-water habitat. The deeper water layers, which include the hypolimnion and the metalimnion (transition zone between the epilimnion and the hypolimnion), are colder and provide suitable conditions for cold-water habitat, provided that sufficient dissolved oxygen is present. Severe oxygen depletion occurs only near the bottom of the reservoir during late summer and fall, so suitable cold-water habitat is present throughout the year.

Because it has a very high flushing rate and receives most of its inflow from Shasta Lake, Keswick Reservoir's water quality is largely determined by the water quality in Shasta Lake at the depth from which water is discharged. The southern-most part of Keswick Reservoir also receives flow from the Spring Creek Drainage and diversions from the Trinity River Basin. These sources occasionally have important effects on water quality in the lower reservoir and in the Sacramento River downstream of Keswick Dam.

Spring Creek Basin is a major source of acid mine drainage and heavy metals contamination in the upper Sacramento River basin (Alpers et al., 2000). Spring Creek flows into Keswick Reservoir about a mile upstream of Keswick Dam and periodically contaminates the lower reservoir and the Sacramento River with toxic metals. Iron Mountain, in the Spring Creek drainage, contains a group of mines that became one of the nation's largest copper producers during the first quarter of the 20th century.

Effluents from these mines were extremely acidic and contained high concentrations of copper, zinc and other metals. The Iron Mountain Mine complex contributes about 82 percent of the heavy metals that enter Keswick Reservoir (The Resources Agency, 1989). Because these effluents drain into Spring Creek, they periodically cause fish kills in Keswick Reservoir and the Sacramento River during periods of high runoff. Mining at the site ceased about 1960, but acid mine drainage continues to contaminate Spring Creek. In 1982, the U.S. Environmental Protection Agency ranked Iron Mountain as one of the highest priority sites on their "Superfund" cleanup list.

The Spring Creek Debris Dam was constructed in 1963 on Spring Creek about a mile upstream of Keswick Reservoir to regulate runoff containing acid mine drainage. The dam can store up to about 5.8 thousand acre-feet of water. The dam is operated to coordinate the discharge of acid mine drainage with dilution flows from Shasta Lake. Because of the limited storage in Spring Creek Reservoir, the reservoir occasionally spills. As a result, levels of copper and zinc have periodically reached levels exceeding tolerance thresholds for salmonid in the Sacramento River (The Resources Agency, 1989). Since 1990, concentrations of heavy metals in acidic drainage from the mines have progressively decreased due to several remedial actions, including construction and operation of a lime neutralization plant (National Marine Fisheries Service (NMFS), 2002).

Keswick Reservoir receives water from the Trinity Basin to augment CVP water supply. The water is transferred from the Trinity Basin at Lewiston Lake via the Clear Creek Tunnel. The tunnel discharges into Whiskeytown Reservoir. Most of the discharge from the reservoir is conveyed via the Spring Creek Tunnel to the Spring Creek Powerplant near the mouth of Spring Creek. A portion of the reservoir storage also discharges to Clear Creek, which enters the Sacramento River downstream of Keswick Dam. Water temperatures in Whiskeytown Reservoir are generally low, and discharges from the reservoir have been used to reduce temperature of storage releases from Keswick Dam for fish protection (NMFS, 2002).

### ***Sacramento River from Keswick Dam to the Red Bluff Diversion Dam***

Water temperature and heavy metals are the principal water quality concerns for the Sacramento River in the Keswick Dam to RBDD reach. As noted previously, pesticides from agricultural

drainage are an important problem for more downstream reaches of the river. Dioxins, a closely related group of highly toxic compounds, have been discharged from a paper mill into the Sacramento River near Anderson. The mill has greatly reduced these discharges and, consequently, a health advisory on consumption of fish from the river between Redding and Red Bluff has been lifted (Reclamation, 1997).

The principal sources of heavy metals to the upper basin of the Sacramento River were discussed in the previous section. Despite recent success in reducing acidic mine drainage from the Iron Mountain Mine complex and other sites, elevated levels of copper are still found in streambed sediments in the Sacramento River downstream of Redding (USGS, 2000). Additional sources of heavy metals affect downstream reaches of the Sacramento River, particularly below the Feather River confluence. Contaminated sediments from historic mining activity in the Feather River, American River, Cache Creek and Putah Creek basins have resulted in high mercury levels in the lower river and the Delta, but mercury levels are not high in the upper river (USGS, 2000).

Water temperature is a very important water quality issue for the Keswick Dam to RBDD reach of the Sacramento River primarily because of habitat requirements for salmonid. Four runs of chinook salmon, all of which are listed or are candidates for listing, and Central Valley steelhead trout, which is also listed, spawn and rear in this reach of the river.

Maximum survival of incubating salmon and steelhead eggs and yolk-sac larvae occurs at water temperatures between 41 and 56 degrees Fahrenheit, with no survival occurring at 62 degrees Fahrenheit or higher (Reclamation, 1997). Winter-run and spring-run chinook salmon, which lost their historic upper elevation spawning habitats when Shasta Dam was built, spawn during late spring and summer and, therefore, are particularly vulnerable to water temperature conditions in the river. Winter-run is listed as endangered and spring-run is listed as threatened under the Federal Endangered Species Act of 1978 (ESA).

For a period after Shasta Dam was constructed, the reservoir was kept relatively full, and cold water released from the hypolimnion provided cooler summer temperatures in the downstream reaches. Cold-water releases create suitable conditions for spawning winter-run and spring-run salmon in the mainstem Sacramento River below Shasta and Keswick Dams. At present, winter-run spawning habitat is almost entirely restricted to the Sacramento River between Keswick Dam and the RBDD; therefore, the survival of winter-run chinook is strongly tied to habitat conditions in this reach. In the 1980s and 1990s, Shasta Lake releases were increased to satisfy increasing spring and summer agricultural and urban water demands. These increased releases, however, depleted Shasta Lake's cold-water pool, resulting in warmer water in the river and high mortalities of salmon eggs.

The NMFS Biological Opinion for winter-run chinook (1993) established water temperature objectives for the river upstream of Jelly's Ferry (near RBDD) of 56 degrees Fahrenheit for the period April 15 through September 30, and 60 degrees for October. Recent changes in reservoir operations, including greater carry-over storage, increased imports of cold water from the Trinity River system and, most importantly, the installation of a temperature control device (TCD) on Shasta Dam, have substantially improved water temperature conditions in the reach (NMFS, 2002). Changes in reservoir storage and operations have the potential to increase cold-water



discharges during summer, which could significantly extend the downstream reach of suitable habitat conditions for spawning by salmonid.

## **Air Quality**

The northern half of the Central Valley is located in the Sacramento Valley Air Basin (SVAB). The Coast Range, the Sierra Nevada Range, the Cascade Mountains, and the San Joaquin Valley Basin bound the basin. Marine winds enter the valley at the Carquinez Straits and head eastward until deflected north into the Sacramento Valley and south into the San Joaquin Valley. A combination of air contaminants, meteorological conditions, and the topographical configuration of the valley affect air quality throughout the Sacramento Valley basin. Most of the air pollutants in the study area may be associated with either urban or agricultural land uses.

Pollutants commonly associated with agricultural land uses include particulate matter less than 10 microns (PM<sub>10</sub>), carbon monoxide (CO), nitrogen oxides (NO), and ozone  $10 \times$  (O<sub>3</sub>) precursors. No clear relationship exists between agricultural acres and the occurrence of O<sub>3</sub>-resulting concentrations of O<sub>3</sub> and PM<sub>10</sub> in the atmosphere.

For a portion of the region in the SVAB, the Pacific high-pressure system during the summer can create inversion layers in the lower elevations that prevent the vertical dispersion of air. As a result, air pollutants in this portion of the region can become concentrated during summer, lowering air quality. During the winter, when the Pacific high-pressure system moves south, stormy, rainy weather intermittently dominates the region. Prevailing winter winds from the southeast disperse pollutants, often resulting in clear, sunny weather and better air quality over most of this portion of the region. Much of the SVAB is designated as a non-attainment area with respect to the national and State O<sub>3</sub> and PM<sub>10</sub> standards, and the urban Sacramento and Maryville/Yuba City area are designated as non attainment for national and State CO standards.

The relatively low residential density of Shasta County's rural residential and suburban residential areas is a major contributor to continuing auto-dependent life-style that adversely affects air quality. Pollution from mobile sources, such as cars and trucks, represents 43 percent of hydrocarbons emissions, 57 percent of NO emissions, 59 percent of reactive organic gases and 82 percent of CO emissions in typical urban areas of Shasta County (Shasta County General Plan).

## **Noise**

Historically, the noise character of the Sacramento River basin was dominated by sounds from natural sources. Beginning in the 1850's, the advent of mining, timber harvesting, and other human activities brought higher noise levels associated with these uses. Today, noise levels in the more densely populated areas of the State are influenced predominantly by the presence of limited-access highways carrying extremely high volumes of traffic, particularly heavy trucks. The construction of new highways, office and industrial facilities, shopping centers, and residential communities produces additional noise. Noise in rural areas, in which traffic generally is low to moderate and construction activity is less predominant, usually is measured at considerably lower decibels. Noise at Shasta Lake is affected by the presence of boats for water

skiers and personal watercraft (Sacramento and San Joaquin River Basins Comprehensive Study, October, 2001).

## **BIOLOGICAL ENVIRONMENT**

Biological resources in the region reflect the area's considerable diversity of climate, topography, and vegetative associations. Much of the area, especially land within the central valley, has been modified by past and present land uses. Cattle grazing, deforestation of the area's oak woodlands, and expansion of agriculture to flood plains substantially altered both the region's floodplain and channel vegetation. Agriculture is currently the primary land use in the region, with riparian vegetation relegated to narrow strips along portions of Sacramento River's main channel and its tributaries.

### **Aquatic and Fishery Resources**

#### ***Introduction***

This section describes the aquatic biological resources of the primary study area. The primary study area includes the Sacramento River between Keswick Dam and the RBDD, Shasta Lake and Keswick Reservoir, and the lower reaches of the major tributaries to the reservoir (the little Sacramento, McCloud, and Pit rivers, and Squaw Creek), which will be inundated if Shasta Lake is enlarged. The section focuses on fish species and their habitats because: 1) fish have a more direct economic importance than other aquatic organisms; 2) public interest in fish is much greater than in other aquatic species; 3) several fish species that occur in the primary study area are federally listed as threatened or endangered; and 4) relatively little information is available for non-fish species.

The fish species assemblages of the Sacramento River include anadromous and resident salmonid and native warm-water river species such as Sacramento sucker and Sacramento pikeminnow. Fish species of Shasta Lake and Keswick Reservoir include primarily introduced warm-water and cold-water species. Shasta Lake tributary species include planted and wild trout and several native species. The primary study area's major non-fish aquatic animal species are benthic macro invertebrates in free-flowing river sections and zooplankton in the reservoirs. **Table 4** provides the common and scientific names of the region's fish species and indicates their primary locations.

#### ***Shasta Lake and its Tributaries and Keswick Reservoir***

The fisheries resources of Shasta Lake are greatly affected by the reservoir's thermal structure. Generally speaking, water temperatures above 68 degrees Fahrenheit favor warm-water fishes such as bass and catfish; and lower temperatures favor cold-water fishes such as trout and salmon. Shasta Lake is classified as warm monomictic, because it has one period of mixing per year. During a limnological survey conducted during 1995 through 1997, the reservoir mixed during the winter months and was thermally stratified from late April through the end of September (Lieberman and Horn, 1998).

**TABLE 4**  
**FISH SPECIES KNOWN TO OCCUR IN THE PRIMARY STUDY AREA**

Common Name	Scientific Name	Shasta Lake Tributaries	Shasta Lake / Keswick Reservoir	Sacramento River - Keswick to Red Bluff
Chinook salmon	<i>Oncorhynchus tshawytscha</i>			
winter-run				X
spring-run				X
fall-run			X	X
late fall-run				X
Kokanee salmon	<i>Oncorhynchus nerka</i>	X	X	
Rainbow trout	<i>Oncorhynchus mykiss</i>	X	X	X
Steelhead trout	<i>Oncorhynchus mykiss</i>			X
Brown trout	<i>Salmo trutta</i>	X	X	
Green sturgeon	<i>Acipenser medirostris</i>			X
White sturgeon	<i>Acipenser transmontanus</i>	X	X	X
Pacific lamprey	<i>Lampetra tridentata</i>			X
Western brook lamprey	<i>Lampetra richardsoni</i>			X
Sacramento sucker	<i>Catostomus occidentalis</i>	X	X	X
Sacramento pikeminnow	<i>Ptychocheilus grandis</i>	X	X	X
Hardhead	<i>Mylopharodon conocephalus</i>	X	X	X
Sacramento blackfish	<i>Orthodon microlepidotus</i>	X	X	
California roach	<i>Hesperoleucus symmetricus</i>	X		X
Speckled dace	<i>Rhinichthys osculus</i>	X	X	
Golden shiner	<i>Notemigonus crysoleucas</i>	X	X	
Carp	<i>Cyprinus carpio</i>	X	X	X
Channel catfish	<i>Ictalurus punctatus</i>	X	X	X
White catfish	<i>Ameiurus catus</i>		X	X
Brown bullhead	<i>Ameiurus nebulosus</i>		X	X
Black bullhead	<i>Ameiurus melas</i>		X	X
Riffle sculpin	<i>Cottus gulosus</i>	X	X	
Prickly sculpin	<i>Cottus asper</i>			X
Largemouth bass	<i>Micropterus salmoides</i>		X	
Smallmouth bass	<i>Micropterus dolomieu</i>	X	X	X
Spotted bass	<i>Micropterus punctulatus</i>	X	X	
Black crappie	<i>Pomoxis nigromaculatus</i>		X	
White crappie	<i>Pomoxis annularis</i>		X	
Bluegill sunfish	<i>Lepomis macrochirus</i>		X	
Green sunfish	<i>Lepomis cyanellus</i>	X	X	
Threadfin shad	<i>Dorosoma petenense</i>		X	

Because of the reservoir's great depth, however, the mixed layer extended only about 160 feet below the surface. The maximum depth of Shasta Lake at full pool is 517 feet. During the period of summer stratification, the warm surface layer, or epilimnion, is about 30 feet deep. Water temperatures in this layer generally peak at about 80 degrees Fahrenheit during August, which is too high to support cold-water fishes, but favorable for warm-water species. The deeper water layers, which include the hypolimnion and the metalimnion (transition zone between the epilimnion and the hypolimnion), are colder and suitable for cold-water species as long as sufficient dissolved oxygen is present. Because severe oxygen depletion occurs only near the

bottom of the reservoir during late summer and fall, suitable habitat conditions for cold-water species are present throughout the year.

The fish habitats of Shasta Lake occupy two ecological zones: the littoral and the pelagic zones. The littoral zone lies along the reservoir margin down to maximum depth of light penetration to the reservoir bottom. This zone supports populations of spotted bass, smallmouth bass, largemouth bass, black crappie, green sunfish, channel catfish, and other warm-water species. Quiet coves with abundant aquatic plants are ideal habitat for bass and sunfish species, but such habitat is limited in Shasta Lake because of its steep shorelines and large seasonal water level fluctuations. Features that add structural complexity to the littoral zone, such as large rocks, snags or drowned brush or trees, generally improve its habitat value.

The pelagic zone is roughly equivalent to the reservoir's epilimnion and the upper metalimnion layers. The epilimnetic portion of this zone is the principal plankton-producing region of the reservoir. Plankton comprises the base of the food web for the reservoir's fish populations, because it supports the fry of most fish species. It also sustains threadfin shad, which feed on zooplankton at all ages and which represent the primary forage species for most of the reservoir's game fishes (Reclamation, 1997).

The metalimnion and hypolimnion support cold-water species such as rainbow trout, brown trout, and landlocked chinook salmon and kokanee salmon. Native species such as white sturgeon, Sacramento blackfish, hardhead minnow, riffle sculpin, Sacramento sucker, and Sacramento pikeminnow reside in cold water near the reservoir bottom. Trout may congregate near the mouths of the reservoir's tributaries when inflow temperatures of these streams are favorable. Summer water temperatures of the lower McCloud River rarely exceed 68 degrees Fahrenheit (North State Resources, Inc., 2003) and provide cold-water habitat in the upper portion of the reservoir arm that receives its inflow.

The lower reaches of the reservoir's tributaries provide spawning habitat for reservoir fish populations, particularly trout, and have important resident fisheries of their own. These tributaries would be inundated if Shasta Lake is enlarged. Most of the native species found in Shasta Lake also inhabit the lower reaches of the tributaries. One of these species, the hardhead minnow, is classified as a State of California Species of Special Concern (Moyle et al., 1995). A few creeks on the western shore of the reservoir are biologically dead because of toxic effluent from local mines (FS, web site).

With respect to fishery resources, the McCloud River is the most important tributary of Shasta Lake. The river has a distinguished history as a world-class salmon and trout stream. Cold, large-volume springs sustained high flows and fairly constant, cool water temperatures throughout the year, enabling resident and anadromous salmonid fishes to thrive (North State Resources, Inc., 2003). The river once supported bull trout, the only char native to California, but the species has been extirpated, probably as a result of changes to the river resulting from construction in 1965 of the McCloud Dam (Moyle, 2002). Construction of the dam greatly altered the flow and sediment regimes of much of the river remaining upstream of Shasta Lake. Despite these effects, however, the lower McCloud River retains excellent fish habitat and an assemblage of native fishes (Moyle, 2002). In recognition of its extraordinary resource values, the McCloud River receives protection under the California Wild and Scenic Rivers Act (the

Act). Although the river has not been designated as “Wild and Scenic”, the Act declared that continued management of the river resources in their existing natural condition represents the best way to protect the unique fishery of the river (North State Resources, Inc., 2003). The Act also explicitly prohibits any department or agency of the State from cooperating in “the planning or construction of any dam, reservoir, diversion, or other water impoundment facility that could have an adverse effect on the free-flowing condition of the McCloud River, or on its wild trout fishery” (North State Resources, Inc., 2003). However, the Act exempts from this prohibition participation by the DWR in studies involving the technical and economic feasibility of enlarging Shasta Dam.

North State Resources, Inc. (2003) conducted a remote (GIS) survey of aquatic habitat in the portion of the McCloud River that would be inundated by raising Shasta Dam as much as 24 feet above its current height, as well as that portion of the river that is currently in the reservoir inundation zone. This portion of the river extends about 1.7 miles upstream of the McCloud Bridge. Limited access to the river precluded on-site surveys. The upper half of this river section is upstream of the maximum pool level of the reservoir and, therefore, has never been inundated. Flatwater habitat (runs, glides and pocket water) and pools, dominate this reach and there is very little riffle habitat. Trout use the flatwater and pool habitats for rearing and foraging, but also require riffle habitat for spawning. This reach of the river has excellent riparian vegetation. The fluctuating water level of the reservoir greatly affects habitat in the lower half of the surveyed portion of the river, the reach between the McCloud Bridge and the maximum pool level. When this reach is inundated by the reservoir, sediment deposits in and along the channel, producing alluvial and deltaic deposits at various elevations below the full pool level. Alternatively, when the reservoir level is low, especially during early-season flood flows, the channel experiences bank and bed erosion. Reoccurring episodes of sedimentation and scour profoundly affect the habitat of this reach. Probably as a result of this process, when the reservoir is drawn down, large, wide, low-gradient riffles with channel braiding dominate the reach. The fluctuating water levels have also reduced riparian vegetation in this reach.

Keswick Reservoir, which extends about 9 miles from Shasta Dam to Keswick Dam, is intermediate as fish habitat between Shasta Lake and the Sacramento River. The movement of its impounded water is much slower than that of the Sacramento River, but much faster than that in Shasta Lake. The average residence time for water is about one day in Keswick Reservoir and almost one year in Shasta Lake. Keswick reservoir receives almost all of its inflow from Shasta Lake. The temperature of these inflows is generally less than 55 degrees Fahrenheit (Lieberman and Horn, 1998). Although this temperature is well below the optimal range for warm-water fishes, the reservoir supports both warm-water fishes, including largemouth bass, crappie and catfish, as well as rainbow trout and other cold-water species (Reclamation, 1997).

Zooplankton of Shasta Lake was investigated during the 1995 through 1997 study of the reservoir’s limnology (Lieberman and Horn, 1998). Cladocerans comprise the dominant zooplankton taxa in the deepest, central portion of the reservoir, but Cladocerans and calanoid copepods are about equally abundant at other locations. Rotifers, which are generally very small but represent an important prey for larval stages of fish, have relatively low abundances.

Zooplankton in Keswick Reservoir result from entrainment of populations in Shasta Lake during storage releases, particularly releases from the epilimnion. Operation of the Shasta Dam TCD,

which helps conserve the reservoir's cold-water pool by accessing epilimnetic water for storage releases in the spring and early summer, may reduce zooplankton biomass, which resides primarily in the reservoir's epilimnion.

Brief descriptions for each of the principal game fish species and native species found in Lake Shasta and its tributaries are given below:

- **Rainbow trout** – Rainbow trout are native to the Sacramento River Basin, but widespread plantings of hatchery-raised rainbow trout have greatly altered the original genetic strains. Catchable-size rainbow trout are planted in Shasta Lake during spring through summer, although some natural reproduction occurs as a consequence of trout spawning during the spring in many of the reservoir's tributaries. Some genetic dilution of wild trout populations in the tributaries has probably occurred as a result of interbreeding with the many strains that have been planted in Shasta Lake, but at least in the McCloud River, available data indicate that this dilution is not significant (North State Resources, Inc., 2003). During summer, trout in Lake Shasta inhabit colder water in the metalimnion. Trout generally prefer water temperatures less than 68 degrees Fahrenheit. Rainbow trout in Shasta Lake prey on zooplankton when young, but switch to benthic invertebrates and fish prey, including threadfin shad, as they grow larger. Shasta Lake has a reputation for growing large rainbow trout (Reclamation, 1997). It has been reported that McCloud River rainbows tend to be more bottom-oriented when feeding than rainbow trout elsewhere (North State Resources, Inc., 2003).
- **Spotted bass, smallmouth bass, and largemouth bass** – These three black basses are very successful introduced species in California. They are the most sought after warm-water game fishes in the State. They are abundant in Shasta Lake and other reservoirs in California, but for reasons not well understood, their abundance has declined since the reservoirs were first formed (Moyle, 2002). All three species are native to the Mississippi River Basin and southeastern United States. Preferred habitat for largemouth bass is beds of aquatic plants in warm, low turbidity lakes and ponds. Shasta Lake, like most California reservoirs, has large seasonal water level fluctuations, which interfere with the development of aquatic vegetation. Perhaps as a result of the dearth of near shore vegetation, adult largemouth bass in California reservoirs often school offshore in the epilimnion. Spotted and smallmouth bass are less dependent on aquatic vegetation than largemouth bass and are currently more abundant in the reservoir.

All three bass species begin spawning in early spring. Smallmouth will spawn at cooler temperatures (55 to 61 degrees Fahrenheit) than spotted bass (65 degrees). Largemouth bass may continue to spawn as late as June. Largemouth and smallmouth bass deposit eggs in nests at a depth of 3 to 6 feet. Smallmouth bass may also spawn in the lower tributary reaches. Rising reservoir levels during spring may submerge nests to depths where water temperatures are too cold for proper development of eggs or sac fry. Spotted bass construct nests in deeper water and are apparently less affected by reservoir water level fluctuations (McGinnis, 1984).

Bass species feed on zooplankton until they reach about 2 to 3 inches in length when they switch to aquatic insects and fish fry. As the bass grow larger, fish become increasingly important in their diet. Optimal temperatures for growth are 68 to 81 degrees Fahrenheit, or warmer. Threadfin shad are important prey for older bass, but they compete with fry for zooplankton, which has probably resulted in reduced survival of bass fry (Moyle, 2002).

The year-round cool water temperatures of the tributaries likely limit significant upstream intrusions from the reservoir by these three black bass species or any of Lake Shasta's other warm-water species.

- **Black crappie** – Black crappie are native to the Mississippi River Basin and the Great Lakes region. In reservoirs, they tend to occur in large schools around large, submerged objects during daylight hours and forage in open water during evenings and early mornings. Spawning begins in March or April as water temperatures reach 57 to 63 degrees Fahrenheit. Spawning may continue as late as July. They construct their nests at a depth of about 3 feet in or near beds of aquatic plants. Crappies are opportunistic, mid-water feeders; zooplankton and small insect larvae are their primary prey. Adult crappie feed mainly on fish. Optimum water temperatures for growth range from 63 to 81 degrees (Reclamation, 1997).
- **Channel catfish** – Channel catfish are native to the Mississippi River Basin. They are omnivorous and opportunistic bottom feeders. Channel catfish spawning occurs from April, when water temperature exceeds 68 degrees Fahrenheit, and may continue through July. They prefer warm water temperatures, in the range of 68 to 86 degrees.
- **Kokanee salmon** – Kokanee salmon are the non-anadromous form of sockeye salmon. They are zooplankton grazers at all ages. Mature Kokanee are generally about 6 to 8 inches long. They generally spawn between early August and early February at temperatures of 43 to 55 degrees Fahrenheit. Most Kokanee spawn in tributary streams a short distance from the reservoir. Kokanee inhabit surface waters of the reservoirs as long as temperatures remain in the preferred range (approximately 43 to 59 degrees) or colder. As surface waters get warmer, the fish move into the hypolimnion.
- **Chinook salmon** – Prior to the construction of Shasta Dam, chinook salmon migrated into the upper Sacramento, McCloud, and Pit rivers above the current location of Shasta Lake (Yoshiyama et al., 2001; Moyle, 2002). At present, however, all chinook salmon in Shasta Lake are hatchery-raised fish planted in the reservoir.
- **Sacramento pikeminnow, hardhead and Sacramento sucker** – These three native California fish species are characteristic of the mid-elevation reaches of most Sacramento Valley streams. They are abundant in Shasta Lake and most of the Pit River and in the lower reaches of other tributaries, including the McCloud River. The three species utilize different locations and food resources within the streams where they co-occur. All three species tend to prefer deep pools and runs. Suckers remain close to the bottom of streams, where they feed on algae, benthic invertebrates and detritus. Hardheads forage on the bottom and the surface, where they feed on invertebrates, fish eggs and small fish in the current drift. Pikeminnows feed mainly on aquatic and terrestrial insects caught in the drift, but become quite predacious on fish, including young trout, as they grow larger.

All three species spawn in the spring over gravel riffles. Pikeminnows and hardhead generally spawn in April when temperatures rise to about 58 degrees Fahrenheit. Suckers initiate spawning runs as early as February at temperatures between 45 and 51 degrees.

- **Bull trout** – Bull trout (*Salvelinus confluentus*) once inhabited the McCloud River, but this population, which was the only bull trout population in California, has been extirpated. Bull trout were last found in the river during the mid-1970's, and their extirpation has been attributed primarily to the construction of McCloud Dam in 1965. This facility blocked spawning migrations and inundated prime spawning and juvenile rearing habitat. Attempts to reintroduce bull trout to the McCloud River from an Oregon population have been unsuccessful. DFG staff has determined that, due to dramatic changes in habitat that have occurred as a result of the McCloud Dam, bull trout probably cannot be successfully reestablished in the river (DFG web page: [www.dfg.ca.gov/hcpb/species](http://www.dfg.ca.gov/hcpb/species); Moyle, 2002).

### ***Sacramento River***

The Sacramento River runs about 59 miles between Keswick Dam and the RBDD. The river in this reach has a stable, largely confined channel with little meander. Riffle habitat with excellent gravel substrates and deep pool habitats are abundant. Immediately below Keswick Dam the river is deeply incised in bedrock with very limited riparian vegetation and no functioning riparian ecosystems. Water temperatures are cool even in late summer because of regulated releases from Shasta Lake and Keswick Reservoir. Near Redding the river comes into the valley and the floodplain broadens. Historically, this area appears to have had wide expanses of riparian forests, but much of the river's riparian zone is currently subject to urban encroachment. This becomes quite extensive in the Anderson/Redding area with homes placed directly within or adjacent to the riparian zone.

The Keswick to Red Bluff reach of the Sacramento River contains a large assemblage of resident and anadromous fish species, including commercially important species and species that are listed as threatened or endangered. The reach produces four separate runs of chinook salmon, which makes it unique among rivers in North America. Despite net losses of gravel since the construction of Shasta Dam, substrates in much of this reach contain gravel needed for spawning by salmonid. This reach provides much of the remaining spawning and rearing habitat of several listed anadromous salmonid. As such, it is one of the most sensitive and important stream reaches in the State.

The salmon that occur in the Sacramento River below Keswick Dam include all four Central Valley runs of chinook salmon: winter-run, spring-run, fall-run, and late fall-run. Winter-run chinook is a Federal (59 FR 440) and State listed endangered species; and spring-run chinook is federally listed as threatened (64 FR 50394) and State listed as endangered. Central Valley fall-run and late fall-run chinook salmon are currently a candidate species for Federal listing (64 FR 50394).

Central Valley steelhead trout, which are federally listed as threatened (64 FR 13347), also occur in the Sacramento River upstream of Red Bluff and spawn in this reach (McEwan, 2001). Most of these runs historically spawned upstream of the current location of Shasta Dam, but their upstream migrations are now blocked by Keswick Dam. With the possible exception of Battle Creek, the Sacramento River and its tributaries above Shasta Dam were the only spawning streams of winter-run chinook salmon (Yoshiyama et al., 2001).



Fortunately, cold water released from Shasta Dam created new spawning habitat in the reach below Keswick Dam. Without these cold-water releases, the winter-run would possibly have been extirpated with the loss of its historic spawning streams. Today, the fall-run, late fall-run and winter-run chinook salmon stocks and the Central Valley steelhead stocks in the Keswick to Red Bluff reach are augmented by production from the Coleman Fish Hatchery on Battle Creek (CALFED Bay-Delta Program (CALFED), 1998).

In addition to the anadromous salmonid, the Sacramento River contains resident rainbow trout and other native fishes. Resident rainbow trout are particularly abundant in the Keswick to Red Bluff reach. Their abundance has been attributed to stable, cool summer flows resulting from Keswick Dam releases designed to enhance habitat conditions for winter-run salmon. The cool, nutrient-rich flows from the reservoir provide excellent rearing conditions for the trout. Other native species that reside in the Sacramento River upstream of Red Bluff include Sacramento pikeminnow, Sacramento sucker and hardhead minnow. As noted earlier, hardhead is a State Species of Special Concern. White sturgeon and green sturgeon are native anadromous species that have been found at the RBDD, but it is not known whether these species migrate upstream of the dam. Green sturgeon has been proposed for Federal listing as endangered or threatened (66 FR 64793).

### ***Life History of Sacramento River Anadromous Fish Species***

Brief life history descriptions for the Sacramento River runs of chinook salmon and steelhead trout are given below. The life history of green sturgeon, a species that has been proposed for Federal listing and that may occur in the primary study area, is also described. A discussion of major factors that affect the distributions and abundances of the anadromous salmonid species in the primary study area is provided following the life history descriptions.

- **Sacramento River Chinook Salmon –**

- **Life History.** Chinook salmon of the Sacramento River migrate from the ocean as two- to seven-year-old adults and spawn upstream in the river and its tributaries. The adults normally return to their natal stream or hatchery. The eggs are deposited in a gravel nest and incubate for a few months before the young fish emerge and enter the water column. The juveniles migrate from upstream natal areas to downstream reaches after rearing for a period of time in freshwater. Juveniles become smolts as they prepare physiologically to enter saltwater. **Table 5** shows seasonal periods of peak migration, spawning, incubation and rearing for each of the four salmon runs in the primary study area.

**TABLE 5**  
**SEASONAL LIFE STAGE PERIODICITY OF CHINOOK SALMON RUNS IN THE**  
**SACRAMENTO RIVER AND TRIBUTARIES UPSTREAM OF RED BLUFF**  
**DIVERSION DAM**

Run/Life Stage Migration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Winter-run												
Adult immigration												
Spawning												
Incubation and emergence												
Rearing												
Juvenile/smolt emigration												
Spring-run												
Adult immigration												
Spawning												
Incubation and emergence												
Rearing												
Juvenile/smolt emigration												
Fall-run												
Adult immigration												
Spawning												
Incubation and emergence												
Rearing												
Juvenile/smolt emigration												
Late fall-run												
Adult immigration												
Spawning												
Incubation and emergence												
Rearing												
Juvenile/smolt emigration*												

\* The period of juvenile/smolt emigration for late fall-run salmon is poorly known

Run-specific life history information for the four salmon runs is provided in the following:

- **Sacramento winter-run chinook (Federally and State listed as endangered species).** Winter-run adults enter the Sacramento River during January through May (Fukushima and Lesh, 1998). They remain in deep pools near spawning grounds in the mainstem Sacramento River between RBDD and Keswick Dam for as long as five months before their eggs ripen. They spawn during mid-April to mid-August. Some spawning may occur in Battle Creek, a tributary of the Keswick Dam to RBDD reach of the Sacramento River (Yoshiyama et al., 2001). Winter-run fry emerge from their nests during July to October and rear in the river and the Delta for five to nine months before migrating to ocean during December through April. The federally designated critical habitat of winter-run chinook salmon includes all of San Francisco Bay north of the Bay Bridge, the Sacramento-San Joaquin Delta, and the Sacramento River upstream to Keswick Dam (59 FR 440).

- **Central Valley spring-run chinook (Federally and State listed as threatened species).**

Spring-run adults enter the Sacramento River from April to July and hold in deep pools near their spawning grounds for several months before spawning. The adults spawn between August and October, with the peak spawning period occurring in September (U.S. Fish and Wildlife Service (FWS), 1995). Spring-run primarily spawn in Deer, Mill, and Butte creeks, and the Feather and Sacramento rivers, upstream of the RBDD. Numbers of the spring-run spawners in the Sacramento River have declined more than those in the other streams during the recent past (64 FR 50394). Small numbers of spring-run chinook spawn in Battle Creek. Restoration measures planned for this stream and Clear Creek and Cottonwood Creek, which are also tributary to Keswick Dam to Red Bluff reach of the Sacramento River, have the potential to substantially increase spring-run spawning and rearing habitat (CALFED, 1998). The federally designated critical habitat of Central Valley spring-run chinook includes all of San Francisco Bay north of the Bay Bridge, the Sacramento-San Joaquin Delta, the Sacramento River and tributaries upstream to Keswick Dam (65 FR 7764).

The timing of many of the spring-run life history events varies depending on their natal stream. The differences may represent natural variability in response to differences in water temperature conditions in different streams, or may result from varying degrees of hybridization with fall-run stocks. Incubation of spring-run eggs in most streams and rivers occurs from August through December, but in Mill and Deer creeks incubation occurs from September through March (FWS, 1995). Spring-run in Deer and Mill creeks typically rear for more than a year and emigrate as yearling smolts the following November through May. Spring-run from Butte Creek and the Sacramento and Feather rivers usually rear during November through June and emigrate as smolts beginning about March (FWS, 1995).

- **Central Valley fall/late fall-run chinook (Federal candidate species).** The NMFS considers the Central Valley fall-run and late fall-run to be genetically indistinguishable (64 FR 50394), but they are phenotypically distinct and DFG and others have long recognized them as separate runs. The Sacramento River fall-run adults migrate upstream to the Sacramento River from August through December (Fukushima and Lesh, 1998). Spawning peaks during October and November, although timing varies from stream to stream. Late fall-run adults enter the river from October through April and spawning peaks during February and March (FWS, 1995). Sacramento River fall-run spawn in the Sacramento River upstream of the Deer Creek confluence and in the Feather, Yuba, and American rivers and tributaries (FWS, 1995). The eggs incubate from October through March and juvenile rearing and smolt emigration occurs from January through June. Late fall-run chinook spawn primarily in the Sacramento River between RBDD and Keswick Dam. Juvenile late fall-run probably begin their seaward migration about July, although the timing of late fall-run emigration is uncertain and may be quite variable. Small numbers of fall-run and/or late fall-run chinook spawn in the tributaries of the Keswick Dam to Red Bluff reach of the Sacramento River including Battle Creek, Clear Creek, Cottonwood Creek, Cow Creek, and Bear Creek. Restoration measures in these streams have the potential to substantially increase spawning and rearing habitat.

• **Central Valley Steelhead (Federally listed as threatened species)**

Steelhead life histories are similar to those of chinook salmon, except that the adults do not necessarily die after spawning and may return to the ocean, repeating their spawning migration

for three or more years. The adults mature in the ocean at age two to four and then migrate upstream toward their natal streams. Adult steelhead are found in the Sacramento River throughout the year but migrations peak in September through March (McEwan, 2001). Spawning occurs in the Sacramento River upstream of the RBDD and in all the major tributaries primarily during December through April. Young Central Valley steelhead typically rear in fresh water for a year and migrate to the ocean during January through May (McEwan, 2001). Small numbers of steelhead spawn in the tributaries of the Keswick Dam to Red Bluff reach of the Sacramento River including Battle Creek, Clear Creek, Cottonwood Creek, Cow Creek, and Bear Creek. Restoration measures in these streams have the potential to substantially increase steelhead spawning and rearing habitat. The federally designated critical habitat of Central Valley steelhead includes all of San Francisco Bay north of the Bay Bridge, the Sacramento-San Joaquin Delta, the San Joaquin River upstream to the Merced River confluence, and the Sacramento River and tributaries upstream to Keswick Dam (65 FR 7764). **Table 6** shows seasonal periods of peak migration, spawning, incubation and rearing for Central Valley steelhead in the primary study area.

**TABLE 6**  
**SEASONAL LIFE STAGE PERIODICITY OF CENTRAL VALLEY STEELHEAD IN**  
**THE SACRAMENTO RIVER AND TRIBUTARIES UPSTREAM OF RED BLUFF**  
**DIVERSION DAM**

Run/Life Stage Migration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Steelhead Trout												
Adult immigration												
Spawning												
Incubation and emergence												
Rearing												
Juvenile/smolt emigration												

- **Green Sturgeon (Proposed for Federal listing)**

Little information exists concerning the life history of green sturgeon. Green sturgeon are anadromous, with most migrating out of freshwater at an age of two or more years. They return to the estuary, as reproductively mature fish, between 12 and 15 years of age and may spawn every 4 to 11 years (Grimaldo and Zeug, 2001). Green sturgeon may live 40 or more years and grow to over 6 feet. Green sturgeon is much less abundant than white sturgeon in the Sacramento River. Both species are benthic feeders and may also prey on small fish.

It is believed that green sturgeon spawn in the Sacramento and Feather rivers between March and July, with peak spawning from mid-April to mid-June (Moyle et al., 1995). They have been found in the Sacramento River upstream to the RBDD and in the Feather River upstream to the Thermalito Afterbay outlet (Moyle et al., 1995; FWS, 1995). Spawning takes place in deep, swift water. The eggs hatch in about a week. For white sturgeon and probably also green sturgeon, some larvae are transported downstream to the Delta soon after hatching, while some remain in the river and later migrate downstream as juveniles.

### ***Factors Affecting Abundance and Distribution of Chinook Salmon and Steelhead***

Many factors have contributed to the decline of chinook salmon in the upper Sacramento River, but the elimination of access to hundreds of miles of historic spawning habitat with the construction of Shasta Dam is certainly the most important factor. Because they spawn during late spring and summer (see **Table 5**), winter-run and spring-run chinook salmon were especially dependent on cool, spring-fed, higher elevation streams that were made inaccessible by the dam. Maximum survival of incubating salmon and steelhead eggs and yolk-sac larvae occurs at water temperatures between 41 and 56 degrees Fahrenheit, with no survival occurring at 62 degrees Fahrenheit or higher (Reclamation, 1997). Central Valley steelhead migrated even further up the Sacramento River and its tributaries than the salmon and, therefore, may have lost even more spawning habitat. Steelhead, which are winter spawners in the Central Valley, were dependent on the cold water streams because of the year-long residency of the juveniles.

For a period after Shasta Dam was constructed, the reservoir was kept relatively full and the cold water released from the hypolimnion provided cooler summer temperatures in the downstream reaches. The cold water releases created suitable conditions for winter-run and spring-run to spawn in the mainstem Sacramento River below Shasta and Keswick Dams. At present, winter-run spawning habitat is almost entirely restricted to the Sacramento River between Keswick Dam and the RBDD and thus the survival of winter-run chinook is strongly tied to habitat conditions in this reach. In the 1980s and 1990s, Shasta Lake storage releases were increased to satisfy increasing spring and summer water demands. The increases depleted the cold-water pool, resulting in warmer water in the river and high mortalities of salmon eggs. Recent changes in reservoir operations, including greater carry-over storage, increased imports of cold water from Trinity River system and, most importantly, the installation of a TCD on Shasta Dam, have improved water temperature conditions in the reach.

The fall-run and late fall-run chinook salmon spawn in the fall and winter, when water temperatures are cooler, and, therefore, they historically spawned more in the lower elevation reaches of the Sacramento River and its tributaries. As a result, these runs were less severely affected than the winter and spring runs by the construction of Shasta and Keswick Dams. Because of the reductions in water temperatures in their historic spawning grounds due to the cold water releases from Shasta, Oroville and other dams, the fall and late fall runs currently spawn earlier in the season than did the historic runs.

Streamflow influences the quantity, quality, and distribution of chinook salmon and steelhead spawning and rearing habitat. Streamflow directly affects the amount of available habitat by determining the stream area with appropriate combinations of water depths, velocities, and streambed characteristics (e.g., substrate composition). It also facilitates downstream migration of juveniles and smolts and provides environmental cues for upstream migrating adults. Flow indirectly affects other habitat properties, including water temperature and other water quality parameters, and production of aquatic invertebrates, a major food source for juvenile salmonids in freshwater. Flow reductions during the incubation period potentially cause inadequate intragravel flow and dewatering of redds, and flushing flows remove harmful quantities of sediment and plant growths from the spawning gravels. Flow fluctuations often result in stranding of juveniles in side channels. Stranding of juvenile winter-run chinook salmon has occurred in the upper Sacramento River following rapid flow reductions associated with

operation of the Anderson-Cottonwood Irrigation District (ACID) dam. Rapid reductions in flood flow releases from Shasta Lake also cause stranding. Reclamation provides minimum flows below Keswick Dam for fall-run chinook salmon that range from 2,300 to 3,900 cfs in normal water years and from 2,000 to 2,800 cfs in critically dry years, and it has reduced flow fluctuations, or ramping rates, from September through December (Corps, 2001).

The improvements in temperature and flow conditions in the Sacramento River have improved habitat conditions for rearing juvenile salmon and steelhead trout. However, these improvements may also affect anadromy of the trout, resulting in more trout remaining in the river to maturity. Resident rainbow trout are genetically equivalent to steelhead trout. The rainbow trout population in the upper Sacramento River (below Keswick Dam) contains both resident and anadromous trout. Habitat conditions affect whether individual steelhead progeny emigrate to the ocean or remain in freshwater to mature as resident trout (McEwan, 2001). Thus, the increased abundance of resident rainbow trout in the Keswick to Red Bluff reach that was noted earlier may be at least partly due to reduced anadromy of the population (McEwan, 2001).

The construction of Shasta Dam blocked gravel recruitment, resulting in the net loss of gravel in the Sacramento River below Keswick Dam. Gravel is transported downstream by high flows, resulting in armoring of the streambed. Suitable gravel is required for salmon and steelhead spawning. A reduction in gravel has degraded spawning habitat below Keswick Dam to at least Clear Creek. Below Clear Creek, tributary streams increase in importance as a source of spawning gravels to the Sacramento River. The problem of gravel availability in the Sacramento River is exacerbated downstream of Keswick Dam by dams constructed on Sacramento River tributaries, bank protection measures in the mainstem of the Sacramento River, and gravel mining enterprises. In the recent past, Reclamation, DWR and DFG have cooperated in actions to artificially replenish salmon spawning gravel in the reach (Reclamation, 1997).

Side channels, undercut stream banks and riparian vegetation are important habitat elements that improve the value of salmon habitat, particularly for rearing juvenile salmon. Some loss of such habitat elements has occurred in the Keswick Dam to RBDD reach of the Sacramento River, but the losses have been much less severe than in the more downstream portions of the river. Nonetheless, preservation of complex rearing habitat in the Keswick to Red Bluff reach is extremely important for protection of the salmon and steelhead runs.

Entrainment of juvenile salmon and steelhead in agricultural diversions is an important source of mortality on the Sacramento River, although the number of diversions in the Keswick to Red Bluff reach is much smaller than that in the downstream reaches of the river and in the Delta. The ACID diversion canal near Anderson is screened but requires frequent maintenance and inspection. Impacts on juvenile winter-run chinook salmon could be especially significant because of the relatively large proportion of this run hatched upstream of this diversion.

Concern is growing that the release of large numbers of hatchery fish can threaten wild fish populations. Potential impacts include direct competition for food and other resources between wild and hatchery fish, predation of hatchery fish on wild fish, genetic dilution of wild fish stocks by hatchery fish allowed to spawn in rivers, and increasing fishing pressure on wild stocks due to hatchery production. Because of increased survival from eggs to smolts under hatchery conditions, fewer adults are needed to maintain a hatchery run. In a mixed fishery of hatchery

and wild fish, a harvest rate based on the hatchery fish will tend to eliminate the wild fish (Hilborn, 1992).

Fish passage problems continue to plague the salmon and steelhead runs in the Sacramento River downstream of the major dams. Construction of the RBDD in 1964 inundated salmon spawning habitat in the Sacramento River upstream of the dam, but more importantly, the dam impeded passage of upstream-migrating adult salmon past the dam and caused excessive losses of downstream-migrating juvenile fish due to predators in the vicinity of the dam. To improve upstream passage of adult winter-run chinook salmon upstream past the RBDD, Reclamation raises the gates at the dam from September through May. Passage for adult salmon is also a problem the ACID diversion dam.

Although largely unquantified, water quality impacts on fish populations in the Sacramento River and its tributaries include effects related to heavy metal pollution (primarily related to spills from Spring Creek Dam), high suspended sediment levels, and elevated nutrient, herbicide, and pesticide levels from agricultural drainage.

## **Vegetation**

### ***Shasta Lake and Vicinity***

The vegetative communities occurring in the Shasta Lake watersheds are a product of geology, soils and climate. Vegetation in the Shasta Lake watershed can be broken down into seven basic vegetation types: Douglas fir-Mixed Conifer forest; Mixed Conifer; Ponderosa Pine; Canyon Oak Woodland; Black Oak Woodland; Gray Pine Woodland; and Chaparral.

Lower elevation vegetation consists of a mix of chaparral and hardwoods; mid-elevation slopes are within a transitional zone that contains both the chaparral/hardwood mix and a mixed conifer component; and higher elevation sites are dominated by mixed conifer overstory with brush species in the understory primarily in open areas. An exception to this is in the riparian corridors where conifers can span from lower to upper elevations.

Montane riparian vegetation (Mayer and Laudenslayer, 1988) is located in narrow belts along many of the tributaries.

### ***Sacramento River Corridor***

Vegetation in the river corridor varies from oak/gray pine and chaparral communities with very limited riparian vegetation above Redding to broad riparian ecosystems and agricultural lands from Redding to Red Bluff.

### ***Riparian***

Riparian vegetation in the primary study area is in the valley foothill riparian association (Mayer and Laudenslayer, 1988). It is typified with a canopy height of 30 m with 20 to 80 percent closure. plant species have specialized adaptations to life in an environment frequently disturbed by flooding and deposition. This vegetative complex provides necessary habitat for many

species of native fish and wildlife. Primary native tree species within the riparian forests of the upper Sacramento River include:

- Fremont cottonwood (*Populus fremontii*)
- White alder (*Alnus rhombifolia*)
- California sycamore (*Plantanus racemosa*)
- Black walnut (*Juglans californica*)
- Oregon ash (*Fraxinus latifolia*)
- Red, black and yellow willow (*Salix spp.*)
- Valley oak (*Quercus lobata*)

There are numerous native shrubs, vines, grasses and sedges within the understory of these trees and, in cases where the tree cover is absent, provide the sole vegetative cover. Additionally, numerous non-native plants have invaded this zone, primarily escapees from urban plantings.

Within the primary study area below Kestwick Dam there are 2,643 acres of existing riparian forests and another 1,178 acres of riparian scrub (Resources Agency, 2000).

Historical riparian ecosystems in California's Central Valley were estimated at 921,000 acres in 1850 but were rapidly depleted, especially along the navigable waterways where trees were cut for lumber and fuel (Jensen et. al., 1993). Much of these were within the 100-year riverine flood plain. These lands were subject to seasonal and permanent flooding and contained a complex mix of aquatic and riparian wetlands along with permanent bodies of water.

The Arkansas Swamp Act of 1850 permitted the states to acquire these lands from the Federal government. California's determination was that 2.2 million acres, most of which were in the Central Valley, met these criteria and was ultimately awarded this acreage by the Federal government. By 1980, primarily due to conversion for agriculture and urbanization, only 102,000 acres (11 percent) of riparian habitat remained, at least half of which was considered to be in a degraded condition (ibid).

Historically, within the upper Sacramento River area, rainfall patterns in the mountains of northern California resulted in maximum flows from December through March. This differed from the spring flood events traditional in the lower river and the San Joaquin River in the southern Central Valley. While flooding of the lands adjacent to the river were an annual event, the lands adjacent to the river above Red Bluff were not considered to have been significantly influenced by seasonal flooding (Warner and Hendix, 1985). Thus, it must be assumed that riparian systems were limited to areas immediately adjacent to the river and along tributary streams. It is unlikely these areas contained the breadth of habitat necessary to support a complex riparian ecosystem as was found in the gallery riparian forests south of Red Bluff.



The reduction in riparian vegetation within the State of California has been extremely high with most estimates indicating a 95 percent reduction statewide. Along the Sacramento River and its tributaries there has been approximately an 89 percent reduction of riparian vegetation from an estimated historical level of 500,000 acres that occupied the river flood plain. Higher terraces along the upper river contained valley oak woodland and adjacent wetlands and shallow lakes created by annual flooding were prevalent.

Reduction of the riparian forests, especially in the lower river, began as a result of the use of trees for lumber and fuel, particularly cordwood for steamboats traveling the river corridors during the late 1800s. More recently, urbanization and agricultural conversion, including their associated flood protection, have been the primary factors eliminating riparian habitat. Water development and reclamation projects, including channelization, dam and levee construction, bank protection, and stream flow regulation have altered the riparian system and contributed to vegetation loss. The highest percentage of riparian vegetation conversion has occurred in the lower Sacramento River and the Delta, with the upper reaches maintaining a higher percentage of remaining natural riparian forest. However, controlled flows below Shasta Dam along with the construction of levees to protect urban areas may have resulted in the narrowing of and already limited riparian zone and elimination of adjacent wetlands that resulted from winter flood flows. Along very limited segments part of the river channel, the processes of flooding and channel movement continue to sustain small “islands” of viable, remnant riparian communities.

There are 59 river miles between Keswick Dam and the RBDD. The river within the primary study areas is, for the most part, unleveed and is generally stable. Immediately below Keswick, the river is deeply incised in bedrock with very limited riparian vegetation and no functioning riparian ecosystems. Near Redding the river comes into the valley and the flood plain broadens. Historically, this area appears to have had wide expanses of riparian forests. The river’s riparian zone from Balls Ferry to Keswick is subject to considerable urban encroachment. This becomes quite extensive in the Anderson/Redding area with homes placed directly within or relatively adjacent to the riparian zone.

### ***Primary River Tributaries***

- Cottonwood Creek
- Battle Creek
- Cow Creek

### ***Upland Vegetation***

Upland habitats in the primary study area is divided into 3 categories based on elevation and soil conditions. These include montane hardwood/conifer and blue oak/digger pine (foothill or grey pine) associations in the southern areas of the lake and downstream to Redding, and valley oak woodland adjacent to the river to Red Bluff (Mayer and Laudenslayer, 1988).

- **Montane hardwood/conifer** – This association ranges from 300 to 1210 m and consists of ponderosa pine, Douglas fir, incense cedar, black oak, Oregon white oak and canyon live oak

with relatively little understory. Because of its variety of vegetation and close proximity to other associations, this habitat type provides for a diverse fauna.

- **Blue oak/foothill pine** – This vegetative type is diverse structurally, horizontally and vertically (Mayer and Laudenslayer, 1988). The understory shrub layer is sparse and may be limited to annual grassland.
- **Valley oak woodland** – This vegetative association varies from savannah-like to more dense forests with partial canopy-closure. Valley oak woodland is usually associated with conditions where trees can put roots into a permanent water supply, such as along drainages. These woodlands provide abundant food and cover for many species of wildlife. In most remaining valley oak complexes, reproduction has been significantly reduced over the past century from urban, agricultural and foraging by domestic livestock.

### ***Wetlands***

While often combined with riparian ecosystems, wetlands within the primary study area are defined as shallow to moderately deep open water areas having a vegetative component of emergent and aquatic species (specifically cattails, rushes and sedge). These are normally the result of annual flooding that breaches natural levees along the river, resulting in shallow pools of semi-permanent water.

Within the primary study area (exclusive of the area within the Lake Shasta basin) there are 32 acres of defined wetland habitat (Resources Agency, 2000).

### ***Sensitive Plants***

Plants considered by the State of California and/or the FS to require special attention are designated as “sensitive.” Plants potentially within the primary study area under this designation are shown in **Table 7**. There are no known populations of listed plants in the primary study area.

Additionally, the CALFED Bay Delta Program has identified silky crypantha, Scott Mtn. Phacelia, Belligner’s meadowfoam, Henderson’s bent grass, and thread-leaved penstemon, as potentials in the primary study area (CALFED, 1997).

**TABLE 7**  
**POTENTIAL HABITAT FOR SPECIAL STATUS PLANTS IN THE SHASTA LAKE WATERSHED<sup>1</sup>**

Species	Status	Habitat	Nearest Population to Watershed
<b><i>Arnica venosa</i></b> Veiny arnica	Endemic	Hot dry slopes under p. pine, black oak and Doug fir. Usually on N-facing aspects or ridgetops. Elevation: 1500-5000 feet.	There are two populations in the watershed: 14-5, T35N, R5W, S 32. 14-30, T33N, R5W, S7&8, and T33N, R6W, S12.
<b><i>Cypripedium fasciculatum</i></b> Clustered lady's slipper	Sensitive	Mixed conifer or oak forests on a variety of soil types, often but not always associated with streams; 1300-6000 feet elev. Widespread but sporadic.	No known populations on the Shasta side of the forest. There are several populations on the Trinity side of the forest.
<b><i>Cypripedium montanum</i></b> Mountain lady's slipper	Sensitive	Mixed conifer or oak forests on a variety of soil types, often but not always associated with streams; 1300-6000 feet elev. Widespread but sporadic.	There is one known population along the Soda Creek Rd., approx. 18 miles N/E of the watershed.
<b><i>Lewisia cantelovii</i></b> Cantelow's lewisia	Sensitive	Moist rock outcrops in broad-leaf & conifer forests; elev. 500 to 3000 feet.	There are two populations near Lamoine, approx. 2 miles north of the watershed.
<b><i>Neviusia cliffonii</i></b> Shasta snow-wreath	Sensitive	North-facing slopes on limestone-derived soils, within riparian zones; Elev. 2400 to 3000 feet?	3 miles east in Waters Gulch. There is a small amount of limestone outcrop in Big Backbone Ck. And Little Backbone Ck.
1) From FS 2001			

## Wildlife

Wildlife resources in the primary study area include habitat conditions suitable for over 200 species of mammals, birds, reptiles and amphibians (Resources Agency, 2000). However, most projections either encompass a much broader area and/or include species because of perceived habitat capability with no information on actual occurrence. Of the various vegetative associations, riparian habitats are the most diverse and in the most limited supply.

Species addressed in this section are limited to those listed under the ESA, the California Endangered Species Act (CESA), the Bureau of Land Management (BLM), and/or State of California designation as being sensitive or of special concern.

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Species addressed in this section are limited to those listed under the ESA, the CESA, BLM and/or State of California designation as of being sensitive or of special concern.

## Listed species

Within the primary study area there is the potential for occupancy by eleven species listed as threatened or endangered under the ESA and/or the CESA (Resources Agency, 2000).

These species, one insect, three fish, two amphibians and five bird species are provided the protection of one or both of these acts and any actions resulting in take must be permitted by the FWS, the DFG.

The listed terrestrial species include:

- **Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)** – Potential habitat for this species occurs in the primary study area. Elderberry bushes are mostly found within riparian zones. Habitat surveys indicate that some scattered elderberry bushes are present in the drainages to Shasta Lake, however the plants are not big enough and too scattered to provide habitat for the elderberry beetle (FS, 2001). Suitable elderberry plants occur along the Sacramento River below Kestwick Dam.
- **Shasta salamander (*Hydromantes shastae*)** – Highly restricted small, isolated, genetically distinct populations. Occupies limestone fissures and caves and other associated habitats within in all successional stages of digger pine-oak, ponderosa pine, and black oak types in an elevation range up to 2500 feet (760 m) (Zeiner, et al., 1988). Populations are known from McCloud River, Pit River, and Squaw Creek arms of Shasta Lake.

Inundation of habitats up to maximum levels would eliminate all of these sites resulting in a 5 percent or greater decrease in occupied habitat (Reclamation, 1985).

- **California red-legged frog (*Rana aurora draytonii*)** – Utilizes areas of slow-moving permanent water and deep pools with shady banks. Thought to be extinct in the primary study area (Hayes and Jennings, 1994).
- **Bald eagle (*Haliaeetus leucocephalus*)** – Large ponderosa pine trees within one mile of Shasta Lake provide existing and potential nest sites for bald eagles. Eagles are more likely to nest in trees that are located close to water. The density of large snags in the southern watershed is generally low due to poor site productivity. Snags provide roosting sites for eagles, as well as habitat for cavity nesting birds (FS, 2001).

There are 18 known bald eagle nest sites adjacent to Lake Shasta. These sites are located in large trees, primarily conifers, the adults defending territories of up to 3 km sq. Bald eagles breed from February to October, the young fledging in 35 to 40 days. Breeding birds are highly subject to human disturbance.

While suitable habitat appears to be available, no bald eagle nests have been located along the Sacramento River. However, wintering birds are known to forage there and as populations continue to increase, nesting may occur in the future. Depending on the increase in elevation of Shasta Lake, bald eagle nest territories could be affected.

- **Swainson's hawk (*Buteo swainsonii*)** – In the Central Valley they nest in riparian areas. This association with riparian habitat is most likely due to the lack of trees in intensively cultivated and industrially-developed areas. Swainson's hawks utilize riparian forests for nesting, utilizing large trees (cottonwoods) on the edge of riparian zones. The populations of Swainson's hawks have declined by 90 percent since the 1940's due to the loss of nesting habitat. In the 1980's

there was an estimated 375 pairs within California, but not all pairs nested (Brown, 2002). There are no known active nests in the primary study area.

- **Peregrine falcon (*Falco peregrinus*)** – This species has recently been de-listed by the Federal government under ESA but remains listed by the State as endangered under CESA. Peregrine falcons may utilize cliff areas near Lake Shasta for breeding, as there is a known historical nest site in Castle Crags. Occasionally a bird may forage along the Sacramento River, however project activities will have no positive or negative effect on the species.
- **Yellow-billed cuckoo (*Coccyzus americanus*)** – Western yellow-billed cuckoos are obligate riparian nesters—they only breed in streamside forests, especially those dominated by willow and cottonwood stands. This species' populations have declined as the riparian forests disappeared. The entire State's cuckoo population is approximately 40 breeding pairs—a decline of over 99 percent from historical levels. It is estimated that fewer than 50 pairs now inhabit riparian areas (Thelander, 1994). Only three California cuckoo populations regularly have more than five breeding pairs. One of these is the Sacramento River between Colusa and Red Bluff (Center for Conservation Biology, 2001).
- **Bank swallow (*Riparia riparia*)** – Nesting colonies utilize the tops of vertical caves and sand banks and in areas that have material that are conducive to foraging such as marshes and along riverbanks. Nests are from 1 to 2 inches wide and from 4 feet to 5 feet in depth. Along riverbanks, erosion control projects such as bank stabilization and flood control projects threaten their habitat. The Sacramento River in California has 70 percent to 80 percent of bank swallows nesting on the riverbanks with 50 percent of this number threatened by projects. In 1994 there were 5 known colonies on the Sacramento River from Red Bluff to Redding with an average of 260 burrows/colony (Gibbons, 1994).

### ***Species of Special Concern***

Species of special concern, while not offered protection under the endangered species acts, require analysis and mitigation under the California Environmental Quality Act. The primary study area has the potential to host 3 amphibians, 1 reptile, 26 birds, and 3 mammals that have been so designated on various lists. Many of these are riparian forest residents. **Table 8** provides a listing of listed and species of special concern within the primary study area.

### ***General Wildlife Habitat***

Raising of the level of Shasta Dam would result in the inundation of terrestrial habitat for many local wildlife species. Actual acres of habitat affected are difficult to compute, as the ratio of actual surface acres of terrestrial habitat to increased surface acres of lake surface is a function of the hypotenuse of the slope. Shoreline slopes in the reservoir portion of the primary study area are variable. Previous estimates have been based solely on surface acre increases that have ranged from approximately 1,000 acres at the low option (6.5 feet) to 30,000+ acres at the high option (200 feet) (USBR, 1999).

**TABLE 8**  
**SPECIAL STATUS SPECIES**

Species	Status	Habitat Specifics
Valley elderberry longhorn beetle	FE	Riparian; requires mature elderberry bushes
Chinook salmon (winter run)	FE	Sacramento River and tributaries below Red Bluff
Steelhead	FT	Sacramento River and tributaries below Red Bluff
Shasta salamander	ST	McCloud River, Pit River and Squaw Creek in moist limestone fissures and caves
Bull trout	ST	McCloud River
California tiger salamander	SC	Wetland and vernal pools and adjacent uplands
Foothill yellow-legged frog	SC	Shallow river and streams with gravel bottoms
Western spadefoot toad	SC	Vernal pools and ponds
California red-legged frog	FT	Still or slow-moving water w/shrubby riparian vegetation. Extinct in primary study area.
Western pond turtle	SC	Moderate to deep slow-moving rivers, ponds and streams having deep pools.
Bald eagle	FT,SE	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Swainson's hawk	ST	Riparian areas w/ large trees for nesting; adjacent open lands for foraging
Ferruginous hawk	SC	Wintering populations only; grasslands.
Cooper's hawk	SC	Riparian zones
Sharp-shinned hawk	SC	Riparian zones
Peregrine falcon	SE	Riparian zones for wintering habitat
Merlin	SC	Riparian zones for wintering habitat
Osprey	SC	Riparian zones along larger rivers and open water areas w/large trees for nesting and roosting
Western least bittern	SC	Marshy areas with emergent vegetative cover
White-faced ibis	SC	Irrigated pastures, shallow marsh
Black tern	SC	Marsh lands w/permanent open water
California gull	SC	Wintering populations only; riverine and wetlands
Long-billed curlew	SC	Grasslands and irrigated pastures
Yellow-billed cuckoo	SE	Riparian forests greater than 50 acres
Burrowing owl	SC	Grasslands
Long-eared owl	SC	Riparian habitat w/dense canopies
Short-eared owl	SC	Open areas with few trees; grasslands, irrigated pastures.
Vaux's swift	SC	Coniferous (Douglas fir) habitats; snags
Bank swallow	ST	Steep river banks and bank near water sources
California horned lark	SC	Grasslands
Loggerhead shrike	SC	Oak woodland
Purple marten	SC	Riparian forests
Tri-colored blackbird	SC	Marsh
Yellow-breasted chat	SC	Riparian scrub
Yellow warbler	SC	Riparian scrub/forests
<i>FE=Federally listed as endangered, SE=State listed as endangered, FT=Federally listed as threatened, ST=State listed as threatened, SC=Regarded by the FWS and/or DFG as a species of special concern.</i>		

## **SOCIAL AND ECONOMIC RESOURCES**

### **Population**

The U.S. Bureau of the Census (BC) determined that the number of persons living in California as of April 1, 2000, totaled almost 33.9 million. The 2000 census counted 2.4 million persons residing within the Sacramento River Valley Region<sup>1</sup> (Sacramento River Region) of whom about three-fourths resided in the Sacramento River Region's southern portion in and near the City of Sacramento. Shasta County (the Redding Metropolitan Area), located in the extreme northern portion of the Sacramento River Region, had 163,256 residents. Population growth during the 1990-2000 decade totaled approximately 4.1 million persons for the State, 328,300 for the Sacramento River Region, and 16,200 for Shasta County. This growth increased the demand for land to accommodate additional roads, parks, housing, retail stores, and office space; the resultant urbanization has converted formerly undeveloped acreage to urban uses.

The California Department of Finance, Demographic Research Unit in May 2002, prepared population estimates as of January 1, 2002 for each county in the State. Based on their estimates, the 20 counties that comprise the Sacramento River Hydrologic Region<sup>2</sup> had a total population of 3.3 million persons; the ten counties comprising the San Joaquin River Hydrologic Region<sup>3</sup> had a combined population of 2.6 million persons; and the four counties included within the Tulare Lake Hydrologic Region<sup>4</sup> had 2,026,500 residents.

### **Land Use**

The primary private land use in the Sacramento River Region is agriculture. As of 1997, California's 74,126 farms included a total of 27.7 million acres. The Sacramento River Region had 11,179 farms with about 4.3 million acres. Shasta County's 850 farms encompassed a total of almost 317,000 acres. Urbanization has been focused along major highway corridors within and near the cities of Sacramento, Fairfield, Woodland, Chico, and Redding. The Sacramento River Region has extensive tracts of Federal and State land, including portions of the Shasta-Trinity, Lassen, Plumas, and Mendocino National Forests, plus several federally or State owned wildlife management areas.

### **Employment and Labor Force**

Data from the U.S. Department of Labor, Bureau of Labor Statistics (BLS) indicate that in August 2002, California's civilian labor force totaled 17.5 million. Further, 16,387,700 of these

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<sup>1</sup> The Sacramento River Valley Region includes the following ten counties in northern California (from north to south): Shasta; Tehama; Butte; Glenn; Colusa; Sutter; Yuba; Yolo; Sacramento; and Solano.

<sup>2</sup> In addition to the ten counties included within the Sacramento River Valley Region, the larger hydrologic region includes the following additional ten counties: Siskiyou; Modoc; Lassen; Plumas; Sierra; Nevada; El Dorado; Placer; Lake; and Napa.

<sup>3</sup> The San Joaquin River Hydrologic Region includes the following ten counties: Amador; Tuolumne; Calaveras; Contra Costa; San Joaquin; Stanislaus; Merced; Mariposa; Madera; and San Benito.

<sup>4</sup> The Tulare Lake Hydrologic Region includes the following counties: Fresno; Kings; Tulare; and Kern.

persons were employed; and 1,115,800 persons (6.4 percent of the area's civilian labor force) were unemployed. During 2001, approximately 1.2 million persons or half of the Sacramento River Region's residents were in the civilian labor force. The Sacramento River Region's unemployed totaled 60,767, or 5.1 percent of its civilian labor force. The Sacramento River Region's rate of unemployment, however, ranged from 4.1 percent in Solano County to 17.6 percent in Colusa County. BLS data also reveal that, for the year 2001, Shasta County had a labor force that averaged 76,487 of whom 71,332 were employed and 5,155 unemployed. This represents an unemployment rate of 6.7 percent.

### **Business and Industrial Activities**

Data from the BC's 2000 County Business Patterns reveal that civilian non-agricultural, non-governmental wage and salary employment in California as of March 2000 totaled approximately 12.9 million persons. Further, the yearly payroll of the State's business establishments, \$514.4 billion, was the largest of any other state, and larger than the economy of many countries. Data collected by the Bureau of Economic Analysis, Regional Economic Information System indicate that, for the year 2000, full- and part-time employment (including farm workers and persons employed by government agencies) averaged 19.7 million persons in the State and almost 1.3 million persons in the Sacramento River Region. Shasta County accounted for 84,800 jobs or 6.6 percent of the Sacramento River Region's employment.

The State's economy is based on: the manufacture of computers and electronic products, transportation equipment (particularly aerospace products), fabricated metal products, machinery, and food processing; business services; and farming. The Sacramento Area's economy is primarily dependent upon the manufacture of computers, electronic products, semiconductors, aerospace products, motor vehicle parts, medical equipment, and food products as well as business services employment and the expenditures of State government agencies. In contrast, the economy of the Sacramento River Region's central and northern counties is based on lumbering and the manufacture of wood products, and farming and food processing. In the year 2000, manufacturing establishments employed 74,046 workers in the Sacramento River Region as a whole. Shasta County manufacturers accounted for 5,039 of these jobs or 6.8 of the Sacramento River Region's total. According to the 1997 Economic Census, the Sacramento River Region's manufacturing sector had sales totaling almost 17.0 billion; and Shasta County's manufacturing establishments earned \$635 million.

Shasta County's economy has expanded as the result of the provision of new health service facilities, shopping centers, and recreational services for non-residents of that county.

### **Local Government and Finance**

Counties, school districts, fire districts, water districts, and other special districts provide local government services in California. The Department of Commerce, BC collects data on the revenues and expenditures as well as the full-time equivalent (FTE) employment of all governmental units that operate within each county. The latest information was obtained from the Bureau's 1997 Census of Government—County Area Finance and Employment Fast Facts. Data for the ten counties that comprise the Sacramento River Region indicate that all local governmental units operating within the Sacramento River Region had revenues totaling almost



\$8.8 billion, representing \$3,950 per regional resident. Shasta County's governmental units had combined revenue of \$644,253,000 or \$3,983 per county resident. Significantly, 41 percent of the combined revenue of all the local governmental units operating within the Sacramento River Region was derived from the transfer of State governmental revenue. Further, local taxes generated 19 percent of the Region's total revenue.

### **Public Health and Safety**

Data from the 1997 Census of Government—County Area Finance and Employment Fast Facts indicate that local governmental units operating within the Sacramento River Region employed 4,164 FTE workers and spent \$309,623,000, or \$139 per regional resident to provide health and hospital services. Local Governmental units in Shasta County spent \$36,015,000 or \$223 per county resident on the provision of public health services. Significantly, Shasta and Tehama counties are the only regional jurisdictions in which hospital care is provided by local government.

State Police, County Sheriffs, fire districts, and county-run detention facilities provide public safety in California's rural areas and smaller incorporated places. Larger cities in the State almost always provide police and fire services within their jurisdictions. In 1997, local governments within the Sacramento River Region employed a total of 7,466 FTE workers to provide police and fire protection. This number included 5,025 FTE workers for police protection and 2,441 for fire protection. Shasta County's local governments employed a total of 467 FTE workers to provide public safety, including 364 for police protection and 103 for fire protection. Annual expenditures for public safety in the Sacramento River Region totaled \$731.6 million or \$329 per regional resident. The provision of public safety in Shasta County cost \$48.0 million or \$297 per county resident.

### **Traffic and Transportation**

California has an extensive system of federally funded interstate highways and State financed limited access highways, and all major population centers have commercial air service at modern airports. In addition, Amtrak provides daily inter-city rail passenger service between: San Diego and Los Angeles; Los Angeles and Santa Barbara; Los Angeles and the San Francisco-Oakland Metropolitan Area; and Bakersfield, Fresno, Modesto, Stockton, and Oakland. In addition, commuter rail services are available between San Francisco and San Jose; Stockton and San Jose; and Los Angeles and various communities in Orange County.

The Sacramento River Region's southern portions have an extensive system of interstate highways and an excellent airport just outside the City of Sacramento. Interstate 5 plus State Routes 99 and 70 are the major traffic arteries serving the central portions of the Sacramento River Region. East-west traffic in the Sacramento River Region is accommodated by I-80 in the south, State routes 20, 162, and 32 in the central portions, and State Routes 36, 44, and 299 in the north. Further, limited commercial air passenger service is available in Redding.

Access to most of the campgrounds, day-use areas, and marina/resorts around Lake Shasta is provided by I-5 and secondary roads maintained by the FS or Shasta County.

Traffic in and around California's major metropolitan areas, including the City of Sacramento, often exceeds the capacity of these area's roads. Excluding Chico, traffic within the central and northern portions of the Sacramento River Region usually is moderate to light. During weekends and holidays from May 1 through Labor Day, however, heavy traffic in the Redding-Shasta Lake area is not unusual.

### **Recreation and Public Access**

Because of its mild year-round climate, forest-covered mountains, accessible beaches, extensive Federal and State lands, and scenic reservoirs, California offers extremely high-quality recreational opportunities for residents and non-residents of the State. Large reservoirs in the State offering a considerable variety of outdoor recreational opportunities (such as power boating, water skiing, fishing, camping, hiking, picnicking, and sightseeing) include Shasta Lake, Trinity Lake, New Melones Reservoir, Lake Berryessa, Folsom Lake, Pine Flat Lake, Isabella Lake, and Millerton Lake.

The Shasta Lake and Trinity Lake area represents the largest array of outdoor recreational opportunities in or near the Sacramento River Region. Other major recreation destinations in or close to the Sacramento River Region include Lake Almanor in Plumas County, Oroville Lake in Butte County, the North Fork Feather River, Lake Berryessa in Napa County, and Folsom Lake, located near the City of Sacramento.

Information from the 1997 Economic Census reveal the importance of outdoor recreation in Shasta County: the County's accommodation and food services establishments had sales totaling \$161.7 million or almost \$1,000 per county resident. This per capita amount is the highest of all the Sacramento River Region's counties. Outdoor recreation and tourism in Shasta County is the result of Shasta Lake, the State's largest. FS personnel in Redding report that the lake has attracted the development of: 11 marinas with 1,075 houseboats, including 625 that are privately owned and 450 that are owned by a marina and rented on a weekly or weekend basis; and 18 developed public campgrounds with a total of 246 sites. In addition, several of the lake's marinas have developed rental campsites and cabins, and there are 158 family-owned cabins on land leased from the FS.

### **Man-made Resources**

Dams, roads, airports, railroads, bridges, pipelines, electric and telephone lines, parks, and government facilities represent infrastructure that permits the development of factories, warehouses, office buildings, retail shopping areas, service centers, and housing developments. In general, the State's and the Sacramento River Region's major metropolitan areas offer sufficient infrastructure to support sustained economic and population growth. In contrast, some of the Sacramento River Region's less urbanized areas lack the high-quality infrastructure (for example, commercial air service) to attract new industrial establishments or large-scale office complexes.

### **Natural Resources**

The State's scenic beaches and mountains, mild climate, extensive rivers with abundant cold-water fisheries, fertile soil, and forested areas have been a major factor behind the in-migration

of persons from other areas. The Sacramento River Region's soil and climate have brought about its development as a major agricultural area specializing in fruits, vegetables, rice, and other farm products. Farm production, in turn, has stimulated the development of food processing establishments as well as businesses that provide services for the area's farms. Similarly, the Sacramento River Region's extensive timber resources have been the catalyst behind the growth of its lumber and wood products manufacturing. Lastly, the development of Shasta Lake has resulted in Shasta County becoming a major outdoor recreational area, which attracts significant numbers of recreationists who reside outside of Shasta County.

## **CULTURAL ENVIRONMENT**

### **Cultural Resources**

As used herein, "cultural resources" include physical resources and intangible cultural values pertaining to paleontology, prehistoric and historic archaeology, history, and Native American ethnography. This assessment is based upon published and unpublished information from various sources, as detailed below. The primary data source is a Class I (literature) survey prepared for Reclamation nearly twenty years ago (Peak and Associates, 1983a, 1983b). Additional information resulting from archaeological surveys or evaluation studies conducted since 1983 is not included. In addition, the study by Peak and Associates does not identify the extent to which the primary study area has been surveyed for archaeological site occurrence. It is therefore impossible to estimate, with currently available data, the extent to which available data adequately represents actual resources present within potential impact areas. This assessment therefore represents a minimum level of potential impact.

### ***Paleontology***

California is geologically diverse, with metamorphic and both intrusive and extrusive igneous rock formations as well as a wide range of fossil-bearing sedimentary rock formations. Within the Shasta Lake area, there are both metasedimentary and metavolcanic formations, and more recent volcanic deposits as well. Sedimentary deposits are prominent in the area. The Triassic Hoselkus Limestone contains both marine invertebrates such as ammonites, and marine vertebrate remains including ichthyosaurs and thallosaurs. Solution caves in the Permian McCloud Limestone contain a significant Pleistocene fauna, including remains of horses, bison, giant bears, dire wolves, ground sloths and mammoths (Merriam, 1906; Munthe and Hirschfield, 1973; Sundahl, 1986a:2). The extent to which these formations are presently affected by Shasta Lake, and potential effects resulting from different dam raise options, cannot be assessed with presently available data.

### ***Prehistoric/Historic Archaeology***

California is rich in both prehistoric and historic archaeological remains. The Central Valley has been an especially productive region, with many deeply stratified sites that have produced information of crucial importance in understanding the prehistory of the State. The Shasta Lake region was little known until quite recently; on into the 1950s it was believed that the area was unoccupied prior to AD 900, after which Shasta Complex remains represented the ancestors of the Wintu people (Smith and Weymouth, 1952; Meighan, 1955; Treganza, 1958). Subsequent investigations revealed repeated occupation of the area as beginning much as eight thousand

years before present. Archaeological remains also represent ancestors of the Yana people (Clewett and Sundahl, 1982; Sundahl and Clewett, 1985; Sundahl, 1986b). Historic archaeological sites represent remains from various historic era activities in the Shasta Lake region, especially relating to fur trapping, mining, early settlement and agriculture (farming and ranching).

Available information fails to clarify the extent to which the primary study area has been surveyed for archaeological remains. Thirty-seven sites were recorded in the 1940s prior to construction of Shasta Dam, by W. D. Weymouth and R. K. Beardsley (Smith and Weymouth, 1952), but it is doubtful that this constituted an intensive survey by contemporary standards. The FS revisited previously recorded sites, and surveyed areas usually inundated, during a drought in 1976-1977, but again it is unclear whether this was a complete survey. Areas above the level of the existing dam apparently have been surveyed on a haphazard and highly incomplete basis (Peak and Associates, 1983a:10, 12; Sundahl, 1986a:1). The proportion of survey coverage in the above-pool area is presently unknown. In comparison to other reservoir areas statewide having potential for enlargement, Peak and Associates (1983a:28) ranked Shasta Lake as having “very high” archaeological sensitivity.

Numbers of known archaeological sites below the level of the existing dam (elevation 1,077.5’), and at various elevations above the existing dam, are shown in **Table 9** below, as tabulated from Peak and Associates (1983b). Peak and Associates’ information indicates that thirty-seven sites are inundated, but one additional site is at an unknown elevation and four more are below the elevation of the lowest outlet. With another seventy-six sites being located above the lowest outlet elevation, but below the crest of the dam, there are at least one hundred eighteen (118) sites actually or potentially affected by the existing dam. Of these, the great majority (101) are prehistoric sites; there are seven historic sites, and 10 multicomponent (prehistoric/historic) sites.

A dam raise of 6.5’, to elevation 1,084’, would inundate an additional six prehistoric sites, at least. Peak and Associates stated that the significance of two of these sites could not be evaluated; three sites were rated as “possibly significant” and another as “probably significant.” Peak and Associates’ significance ranking was based on National Register criteria, but it was noted that this was a very rough estimation only and that many site forms were lacking in needed information (Peak and Associates, 1983a:18-20).

A dam raise of 102.5’, to elevation 1,180’, would inundate the six sites noted above, plus at least another twenty-nine sites. Of the thirty-five sites that would be inundated by the intermediate dam option, thirty-two are prehistoric and three are historic. Peak and Associates stated that four sites could not be evaluated for significance; they ranked eighteen sites as “possibly significant” and thirteen as “probably significant.”

A dam raise of 202.5’, to elevation 1,280’, would inundate the thirty-five sites noted above, plus at least another twenty sites. Of the fifty-five sites that would be inundated by the high raise dam option, fifty are prehistoric, four are historic and one is multicomponent. Peak and Associates stated that six sites could not be evaluated for significance; they ranked twenty-two sites as “possibly significant” and twenty-seven as “probably significant.”

**TABLE 9**  
**PREHISTORIC AND HISTORIC ARCHAEOLOGICAL SITES.**

Resource and Significance	Currently Affected	Additional Sites Located Along Perimeter of Shasta Lake		
		Located within 6.5 feet of Existing Gross Pool	Located within 100 feet of Existing Gross Pool	Located within 200 feet of Existing Gross Pool
<b><i>Prehistoric sites</i></b>				
Unable to evaluate	12	2	4	6
Possibly significant	42	3	16	19
Probably significant	47	1	12	25
<b><i>Total</i></b>	<b><i>101</i></b>	<b><i>6</i></b>	<b><i>32</i></b>	<b><i>50</i></b>
<b><i>Historic sites</i></b>				
Unable to evaluate	3	0	0	0
Possibly significant	2	0	2	3
Probably significant	2	0	1	1
<b><i>Total</i></b>	<b><i>7</i></b>	<b><i>0</i></b>	<b><i>3</i></b>	<b><i>4</i></b>
<b><i>Complex (multicomponent) sites</i></b>				
Unable to evaluate	0	0	0	0
Possibly significant	4	0	0	0
Probably significant	6	0	0	1
<b><i>Total</i></b>	<b><i>10</i></b>	<b><i>0</i></b>	<b><i>0</i></b>	<b><i>1</i></b>
<b><i>Total number of sites</i></b>	<b><i>118</i></b>	<b><i>6</i></b>	<b><i>35</i></b>	<b><i>55</i></b>

## ***History***

Northern portions of California's Central Valley are unmentioned in records of the Spanish and Mexican-era activities so important to more southerly coastal portions of the State. The earliest historic records pertaining to the Shasta Lake area are from Hudson's Bay Company fur trappers (Hunt, 1967). Malaria, introduced by fur trappers in the area, had devastating effects on aboriginal populations in Sacramento Valley (LaPenä, 1978). Gold, copper and iron mining were important activities in the Shasta Lake area during the latter half of the nineteenth century, and later activities included settlement by farmers and ranchers (Petersen, 1965; Lydon and O'Brien, 1974; Sundahl, 1986a:6-9). Most known historic archaeological sites are related to mining, transportation, commerce and recreation (Peak and Associates, 1983a:54). In comparison to other reservoir areas statewide having potential for enlargement, Peak and Associates (1983a:57) ranked Shasta Lake as having "medium" historic sensitivity. Currently available data are insufficient for identifying standing historic structures that might be affected by an enlarged Shasta Dam, and there is no information basis upon which to compare impacts of the various dam raise options.

## ***Ethnography***

California is home to many linguistically and culturally diverse Native American groups. The Shasta Lake area is almost entirely within the traditional territory of the Wintu, a group whose language belongs to the Penutian family (LaPenä, 1978). These people are believed to have arrived in California around 1,000 BC. The Wintu lived primarily in large villages along the

rivers in their territory; they fished for chinook salmon in the McCloud and Sacramento rivers, and hunted deer and other animals. They also ate large quantities of acorns and other vegetable foods. Many Wintu people were displaced in the twentieth century by dams which flooded their homes. Several local groups lived within the Shasta Lake area, including the *Nomtipom*, the *Winimem*, and the *Waimuk* (DuBois, 1935).

The Okwanuchu were another group, related to the Hoka-speaking Shasta people in southern Oregon, who lived in the McCloud River drainage. Another distinct group was the *Madesi* band of Achumawi farther east along Pit River (Olmstead and Stewart, 1978). In addition, the Central Yana people held territory in the Cow Creek drainage (Sapir and Spier, 1943).

Peak and Peak (1983a) noted the presence of numerous sacred sites within the area that would be impacted by an enlarged Shasta Dam. These include burials and cemeteries, places of spiritual power, named villages, and other sites of special concern. Their inventory noted one hundred twenty-six ethnographic and ethnohistoric sites, some but not all of which overlap with archaeological sites. The California Native American Heritage Commission identified a number of locations of particular concern. In comparison to other reservoir areas statewide having potential for enlargement, Peak and Associates (1983a:36) ranked Shasta Lake as having “high” significance in terms of ethnographic sites. Currently available data are insufficient for comparison of potential impacts from the various dam raise options.

### **Aesthetics**

Agricultural uses in the Sacramento Valley, grasslands and woodlands in the foothills, and forests in the upper watersheds characterize visual resources in the Sacramento River Region. The conversion of valley areas from grasslands, floodplains, and extensive riparian areas to cropland, rice fields, and orchards has reduced visual variety. The Sacramento River Region’s upper watershed has retained its predominantly oak woodland, grasslands, forests, and small rural communities despite substantial development along Federal and State highways in the foothills and mountain areas. These areas are framed by the forested ridgelines of the Sierra Nevada to the east, the Cascade Range to the north, and the Coast Ranges to the west. Little urbanization in these areas has preserved pristine wildernesses, mountains, and other dramatic landscapes.

Agricultural uses in the Sacramento Valley, grasslands and woodlands in the foothills, and forests in the upper watersheds characterize visual resources in the Sacramento River Region. The historical changes in the Sacramento Valley from grasslands, floodplains, and extensive riparian areas to cropland, rice fields, and orchards have reduced visual variety. Prior to the 1940’s, the Sacramento Valley was made up of grasslands, scattered oak woodlands, wetlands, vernal pools, and riparian areas. The Sacramento River Region’s upper watershed retained its predominantly oak woodland, grasslands, forests, and small rural communities despite substantial development along Federal and State highways in the foothills and mountain areas. These areas are framed by the forested ridgelines of the Sierra Nevada to the east, the Cascade Range to the north, and the Coast Ranges to the west. Little urbanization in these areas has preserved pristine wildernesses, mountains, and other dramatic landscapes.

Constructing dams and reservoirs substantially changed the visual landscape. Shasta added visual variety to this region. Viewer sensitivity is high in these areas because of high recreation use and easy public access.

A scenic highway is a road designated by the State of California or local agencies as having exceptional scenic qualities or affording panoramic vistas. Highway 151 (from Shasta Dam to near Summit City) is officially designated a State scenic highway (Sacramento and San Joaquin River Basins Comprehensive Study, October 2001).

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